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Adaptive beamforming algorithm with increased speed and improved reliability for smart antennas

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ABSTRACT

In this paper, a novel adaptive beamforming algorithm has been proposed which can be used for tracking the subscribers of a smart antenna in a wide angle spread environment. It can be adapted for arbitrary variations in both eigenvalues and eigenvectors of the autocorrelation matrix of received signal which is mostly the case for moving subscribers' environment. Moreover, it uses one adaptive module which is less than two adaptive modules of previous works and leads to a high speed at least two times more than previous works.

1. Introduction

In general, a channel vector model for the uplink mobile communication assumes a narrow angle spread, which is the case for base stations with tall antenna heights. Therefore, most beamforming algorithms have been developed for the case of a narrow angle spread. Some of these beamforming algorithms have been proposed in [1,2], in which one eigenvector of autocorrelation matrix of received signal is computed to form the optimal weight vector. The performance of the beamforming algorithms developed for narrow angle spread degrades considerably as the angle spread increases. Studies have shown that in the case of a wide angle spread, two eigenvectors with the largest eigenvalues of the autocorrelation matrix should be computed to form the optimal weight vector [6,7]. Although Siriteanu and Blostein [6] and Zekavat et al. [7] present the main idea of using two eigenvectors of the autocorrelation matrix of the received signal, but do not contain answer to the question that how the eigenvalues and eigenvectors of the autocorrelation matrix can be calculated. Lee and Choi [4] try to present a computational procedure to compute eigenvalues and eigenvectors of the autocorrelation matrix of the received signal. On the other hand, for mobile communication when the subscribers are moving during their communication with the smart antenna, the autocorrelation matrix and its eigenvalues and eigenvectors vary without a rule that can be understood conveniently. For special scenarios of these variations the beamforming procedure of Lee and Choi [4] cannot provide a desirable response. This means the reliability of this beamforming procedure is not showable in a firm way for use in a smart antenna, because the presented scenario can be possible to occur. In this paper, an improved adaptive beamforming algorithm has been proposed which can be used for tracking the subscribers in a smart antenna with a wide angle spread environment when there are arbitrary variations in both eigenvalues and eigenvectors of the autocorrelation matrix of the received signal.

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Moreover, the number of adaptive modules in the proposed algorithm is less than the previous work [4] which is a reason for achieving a high speed.

2. Previous weaker works

So far, smart antennas are studied for the purposes of enhancing the base station performance in multipath fading conditions and increasing SNR of the receiver [2,5,8]. In these works the main purpose is to compute an optimal weight vector to use in a smart antenna array for phase and amplitude shifting. Siriteanu and Blostein [6] and Zekavat et al. [7] show importance of using two eigenvectors in computation of weight vector and to apply them in a smart antenna system in order to improve BER (Bit Error Rate) performance in a wide angle spread environment. Siriteanu and Blostein [6] analyze maximal ratio eigen-combining as an alternative to conventional maximum average SNR beamforming as well as maximal ratio combining in scenarios with practically correlated channel gains. Zekavat et al. [7] present a novel merger of an adaptive smart antenna maximum noise fraction beamforming, which maximizes the SNR and leads to a generalized singular value decomposition, and MC-CDMA systems. But, Siriteanu and Blostein [6] and Zekavat et al. [7] do not present how to calculate the eigenvalues and eigenvectors to improve the BER performance, which is the main purpose of a smart antenna's digital environment. In this section, we represent previous works that are done in order to calculate the suitable eigenvalues and eigenvectors of the autocorrelation matrix of received signals of a smart antenna that should finally form the optimal weight vector for a wide angle spread environment. These works have some weakpoints, and their performance compared to the performance of the solution presented in this paper is discussed in the subsequent sections.

From [4], in a smart antenna consider $\mathbf{y}$ is the received signal vector. The weight vector maximizing the SNR can be obtained from the eigenvector corresponding to the largest eigenvalue of the following eigen-equation:

$$\mathbf{R_{yy}w} = \lambda \mathbf{w}$$

where $\mathbf{R_{yy}}$ is the autocorrelation matrix of the received signal vector obtained at the output of the despreader. Fig. 1 shows the flow chart of eigen-space based Lagrange algorithm in [4].

In order to obtain a more appropriate weight vector in the signal environment of a wide angle spread, the weight vector is to be found in eigen-space [4]. From [4], considering more than two eigenvectors is not very helpful and does not conspicuously improve the performance. It particularly means that the weight vector is computed as a combination of the primary and secondary eigenvectors. Consequently, the weight vector is computed as a linear combination of the two primary eigenvectors as follows:

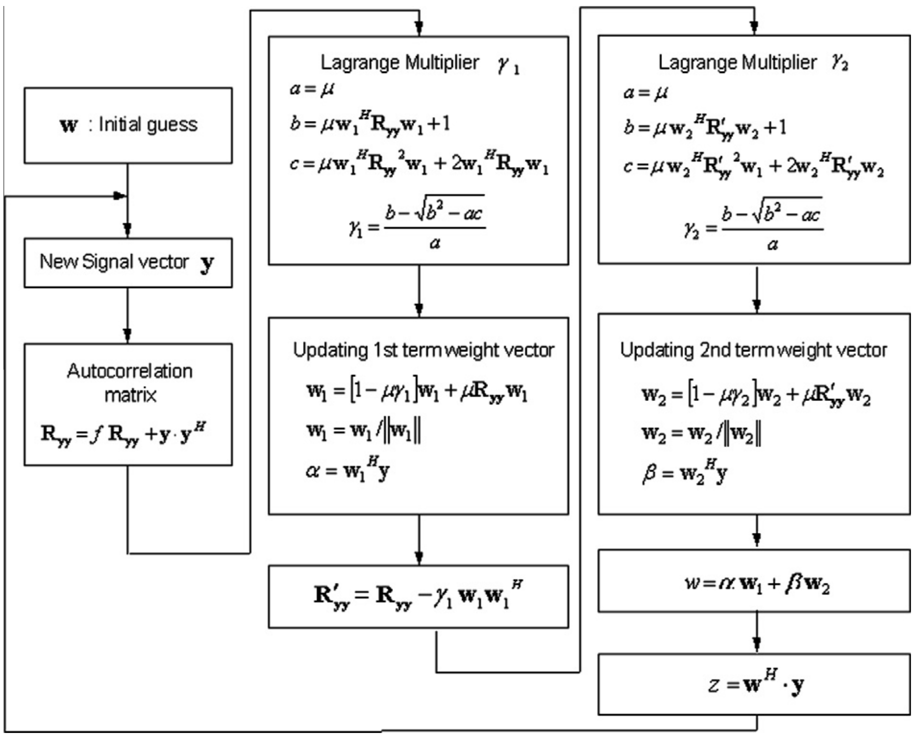

Fig. 1. Flow chart of eigen-space based Lagrange algorithm.