A MIMO Adaptive Beamforming Algorithm for Smart Antennas

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스마트안테나용 MIMO 적응빔형성 알고리즘

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요 약

MUD 적응빔형성 알고리즘을 제안한다. 본 알고리즘은 기준신호를 필요로하지 않는 Blind 방식이며 두단계로 이뤄진다. 첫 번째 단계는 수신신호의 대략의 위치를 파악하는 탐색단계이고, 두 번째 단계는 첫 번째 단계에서 파악된 각각의 위치를 이용해서 정확한 입사신호의 위치와 신호를 검출해낸다. 컴퓨터 시뮬레이션은 다중경로 Rayleigh Fading 채널의 CDMA 환경에서 구현했다.

ABSTRACT

We propose a new MUD adaptive beamforming algorithm. It requires no reference signal and consists of two processing stages. The first stage performs a scan function, and the second stage performs an adaptive beamforming algorithm. Computer simulations, considering multi-path Rayleigh Fading Channel in CDMA, are presented to verify the performance.

키워드

MIMO, adaptive beamforming, smart antenna, CDMA

Ⅰ. Introduction

Recently, due to the limited radio resource, the methods to increase the channel capacity of wireless communications have been greatly demanded. Smart antenna technology seems to be a good candidate to resolve the issue. Throughout an intensive research work on the so-called adaptive beamforming algorithms, several algorithms have been proposed for smart antenna applications [1], [2]. These algorithms can be divided into two main categories. The first category includes the algorithms that are based on the gradient or steepest-descent method, namely minimum mean square error (MMSE), least mean squares (LMS), least squares constant modulus algorithm (LS-CMA), and decision directed algorithm (DD) [1]. The second one includes the algorithms that are based on maximum likelihood (ML) criterion such as iterative least squares projection (ILSP) and iterative least squares with enumeration (ILSE) [2]. More recently, several research results have been reported on multi-input multi-output (MIMO) adaptive beamforming algorithms [3]. The main advantage of MIMO algorithm is that it can simultaneously detect several users. Consequently, by using MIMO technology, we can dramatically increase the capacity of the communications channel. In this paper, we propose a MIMO algorithm, namely scan-MIMO (SMIMO), together with the computer simulation results for the verification of its performance.

In Rayleigh fading channel, where the Doppler effects are taken into consideration, the received signal vector is expressed in equation (1) [4].

$$\vec{x}(t)=\sum_{k=1}^{M}(r_k e^{j\phi_k}) s_k(t)\vec{a}(\theta_k)+\vec{n}(t) \quad (1)$$

where, the received signal vector ($\vec{x}(x)$) and steering vector ($\vec{a}(\theta_k)$) are defined as the following equations:

$$\vec{x}(t)=[x_0(t),\ x_1(t),\ \cdots,\ x_{N-1}(t)]^T \quad (2)$$

$$\vec{a}(\theta_k)=[1\ \exp(-j\pi\sin\theta_k)\ \cdots\ \exp(-j(N-1)\pi\sin\theta_k)] \quad (3)$$

And, $\vec{n}(t)$ is AWGN. $s_k(t)$ is the k-th users signal impinging into the array antenna. The r_k and ϕ_k are the magnitude and phase of the Rayleigh fading factor, respectively [4].

II. Proposed MIMO algorithm

: As shown in Fig. 1, the proposed MIMO model is composed of two operation stages besides the RF processing part.

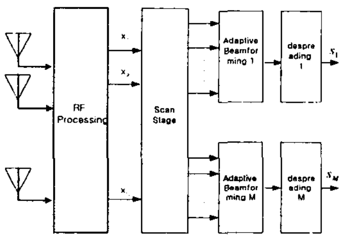

Fig. 1 Scan MIMO model

1) Scan stage : The scan stage roughly detects the incident directions of several users. The function of this stage can be described as follows. First, a scanning vector $\vec{b}(\theta)=[1\ \exp(-j\pi\sin\theta)\ \cdots\ \exp(-j(N-1)\pi\sin\theta)]$ is generated, then the calculationof the inner product, which actually is a cross-correlation calculation, between the received signal vector at the array antenna $\vec{x}(t)$, and the scanning vector $\vec{b}(\theta)$ is performed. In this step, the scanning angle θ is varied from -90 to +90 degrees. In other words, $\vec{b}(\theta)^H\vec{x}(t)$ is calculated for each θ from -90 to +90 degrees. As a result, we can find a correlation beam pattern of the incident signals. In the beam pattern, there will be several peaks, and the angles corresponding to these peaks are the directions of the incident signals. From the peaks of the correlation beam pattern, several angles that generate the highest peaks are selected by a selected rule. The chosen angles are the rough angles of the incident users, not the exact ones. These initial rough angles are applied to the second stage, where a convergence technique of a gradient algorithm is used to search the exact incident directions of users.

2) Adaptive beamforming stage : At the second stage, the exact users signals can be derived by applying a gradient algorithm to converge the rough angles found in the scan stage into the exact incident angles. Each angle searched at the first stage serves as initial angle of each weight vector in the gradient algorithm. In this work, for the adaptive beamforming algorithm, we propose a new projection minimum mean square (PMMSE) algorithm. The PMMSE is a blind beamforming version of conventional MMSE algorithm. The cost function of a conventional MMSE algorithm is [1]:

$$J(\vec{w})=E[\,|\vec{w}^H\vec{x(k)}-d_k|^2] \quad (4)$$

where, d_k is reference signal. An adaptive solution that minimizes the cost function can be expressed as [1]:,

$$\vec{w}(k+1)=\vec{w}(k)-\frac{1}{2}u\nabla J(\vec{w}) \quad (5)$$

The output of the array is given by

$$y(k)=\overline{w^H}(k)\vec{x}(k) \quad (6)$$

In the proposed PMMSE algorithm, after

finding $y(k)$ as in equation (6), we estimate the reference signal by projecting $y(k)$ onto the finite signal constellation, that is $d_k = \Pr[y(k)]$. Therefore the cost function is transformed to $J(\vec{w}) = E[\,|\vec{w}^H \vec{x}(k) - \Pr[y(k)]|^2]$. The other procedures are exactly the same as in the conventional MMSE algorithm.

III. Analysis and simulation

Fig. 2 compares the average bit error rate (BER) performance of the SMIMO algorithm, with the BER of conventional ILSP algorithm as a function of signal to noise ratio (SNR) in the AWGN channel and in the AWGN with multi-path Rayleigh Fading channel. It is noted that the number of users of SMIMO is 4 while that of ILSP is only 1. The number of array antennas is 10. Here, we assume that the mobile user is moving at the velocity of 50km/h, the center frequency is 900Mhz, and the number of multi-path is 26. For the CDMA environment, the processing gain is 64. The BER data of SMIMO is the average value of all users.

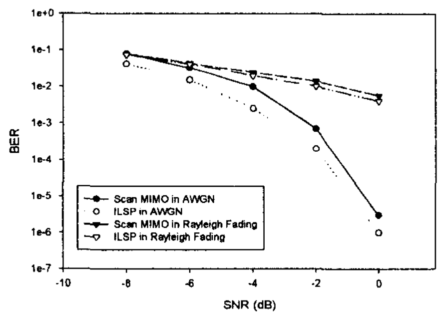

Fig. 2 BER performance

As shown in the figure, the BER performance of the SMIMO is slightly worse than that of ILSP in the AWGN channel. However, when Rayleigh fading is taken into account, the BER of SMIMO is very comparable to that of ILSP. But overall, SMIMOs performance seems good if we consider the fact that it extracts several users at the same time, unlike the ILSP algorithm just used for single user.

Fig. 3 illustrates the beam pattern of the array antenna at the initial state as well as at the final state, where the incident angle of each user converges to the exact value. The incident angles of the four users are 20, 0, 20, 50 degrees. The simulation environment was the same as Fig. 3 in Fig. 2, except for 4 dB of SNR. After completing the operation of the adaptive beamforming algorithm, the final beam pattern exactly indicates the incident directions of all users.

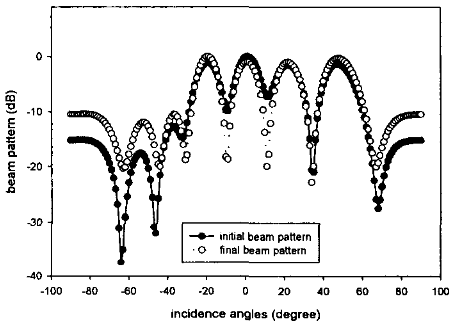

Fig. 3 Array antenna beam pattern

IV. Conclusions

We proposed a novel MIMO model and its algorithm for smart antennas in CDMA. The algorithm was composed of two stages, namely scan stage and adaptive beamforming stage. By the computer simulation, we showed that the performance of the proposed algorithm is highly acceptable in a real-time wireless CDMA environment.

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