Sequential LS Algorithms for Smart Antennas

Jaedon Park, Le Minh Tuan, Giwan Yoon, and Jewoo Kim

스마트안테나용 S-LS 알고리즘

박재돈, Le Minh Tuan, 윤기완, 김제우

요 약

ILSP 알고리즘의 계산량을 줄일수 있는 알고리즘을 제안한다. 블록단위로 계산되는 기존의 알고리즘과 달리, Sequential 하게 계산을 진행하므로 계산량이 매우 감소된다. 그러나, 성능은 기존의 알고리즘과 똑같은 결과를 보여준다. Rayleigh Fading 채널의 CDMA 환경에서 시뮬레이션을 구현했다.

ABSTRACT

We propose a novel method to simplify the computational load of ILSP algorithm for CDMA environment. Since this method processes the block matrix by a vector sequentially, the complex matrix computation can be avoided. The performance of the algorithm is verified by computer simulations.

키워드

LS, adaptive beamforming, smart antenna, CDMA

I. Introduction

Future wireless communications require increasingly higher channel capacity. In general, CDMA and smart antenna are used to enlarge the channel capacity. The key principle of smart antenna is to maximize antenna gain toward the incidence direction of desired signals and to minimize toward the incidence direction of interference signals [1].

Reportedly, there are several smart antenna algorithms such as maximum likelihood (ML), statistically optimum beamforming and decision directed methods [1-4]. ML method is good in its performance at the cost of computational complexity. Iterative least square projection (ILSP) method has reduced the computational complexity of the ML algorithm by making the computation iteratively.

In this paper, we propose two novel simplified algorithms, namely sequential least square projection of moving average (SLSP-MA) and sequential least square projection of forgetting memory (SLSP-FM). Both algorithms have further reduced the computational complexity of ILSP algorithm.

II. System Modeling

We use a linearly equal spaced array antenna. The space is $\frac{\lambda}{2}$, where λ is wavelength. Let the number of array antennas and incident signals be M and D, respectively. The incident signal of m-th antenna is given by

$$x_m(t) = \sum_{k=1}^{D} s_k(t) e^{-j\pi(m-1)\sin\theta_k} + v_m(t) \qquad (1)$$

Here $s_k(t)$ and θ_k are the k-th user's signal and incident angle, respectively. The $v_m(t)$ is addivtive white gaussian noise (AWGN) which is added to m-th antenna.

The equation (1) can be converted to the following equation.

$$X = AS + V \qquad (2)$$

$X = [\ X(1)\ X(2)\ \cdots\ X(N)]$ is $M \times N$ incident signal vector of array antenna, $A = [\ A_1\ \ A_2\ \cdots\ \ A_D]$ is $M \times D$ steering matrix, $S = [\ S_1\ \ S_2\ \cdots\ \ S_D]^T$ is $D \times N$ transmitted signal matrix, and V is $M \times N$ noise matrix. $X(n)$ is the incident signal of array antenna at the n-th snapshot, S_k and A_k are k-th source's transmitted signal and its steering vector, respectively. In a CDMA environment, after the received signal is despreaded, the interference signals are canceled. So, we can redefine $S \equiv S_1,\ A \equiv A_1$.

III. Conventional algorithms

At first, there is ILSP method to estimate the desired signals. The ILSP minimizes the least squares function of equation (3), iteratively using equations (4) and (5) [2].

$$\min_{A,S} = \| X - AS \|_F^2 \qquad (3)$$

$$S = (\ A^H A)^{-1}\ A^H X \qquad (4)$$

$$A = X\ S^H\ (S\ S^H)^{-1} \qquad (5)$$

At second, there is modified conjugate gradient method (MCGM), based on eigenvalue decomposition [4]. The MCGM is designed to maximize the array antenna output power. Although the MCGM is considerably simple in computational load compared with ILSP, the performance of MCGM is preceded by that of ILSP.

IV. Proposed Algorithms

In spite of the good performance of ILSP, its computational complexity $O(MN)$ si very high. We propose a simplified version of ILSP, namely LSLP, whose computational complexity is $O(M)$, where M is the number of antennas, and N is the number of snapshots. In addition to its reduced computational load, SLSP is comparable in performance to ILSP, as shown in **Fig. 1** and **2**. The SLSP is summarized as follows.

1) given

$$A = [\ a_1\ \ a_2\ \cdots\ \ a_M]^T$$

2) update

$$s(N) = \sum_{m=1}^{M} a_m^*\ x_m(N)$$

$$a_m = \sum_{n=1}^{N} s^*(n)\ x_m(n) = a_m + s^*(N)\ x_m(N)$$

where, $m = 1, 2, \cdots, M.$

As a model of SLSP, we propose SLSP-MA method, which uses the so-called moving average. It maintains the number of signals in the processing of computation, by pulling out the first input signal as a new signal is received. This algorithm transforms a part of the 2nd stage of upper SLSP algorithm as follows.

$$a_m = a_m - s^*(1)\ x_m(1) + s^*(N)\ x_m(N)$$

This method needs some memory to store signals during N snapshots.

As a method to remove old signals without using a memory, we propose a method of multiplying the forgetting factor (f). This method transforms a part of upper algorithm as follows.

$$a_m = f\ a_m + s^*(N)\ x_m(N)$$

V. Simulation results and comparisons

Fig. 1 shows the bit error rate (BER) performances as a function of signal to noise ratio (SNR) with and without considering the Multi-path Rayleigh Fading Channel. The processing gain is 64, the number of interference signals is 20, and the number of array antennas is 10. Here, the mobile user is moving at the velocity of 50km/h, the center frequency is 900Mhz, and the number of multi-path is 20. As shown in the figure, in performance, the proposed SLSP algorithms are comparable to ILSP, and much better than MCGM.

Fig. 2 shows the BER performance corresponding to the number of array antennas with and without considering the Multi-path Rayleigh Fading. Here, the SNR is fixed 4dB. The conditions of the other simulation environments factors are the same as those used in **Fig. 1**. In performance, the SLSP algorithms are almost the same as ILSP algorithm, and much better than MCGM, as shown in **Fig. 2**.

Table I Comparison of computational load.

algorithm	computation
ILSP	$6MN+12M$
MGCM	$18M^2+32M$
SLSP-MA	$16M$
SLSP-FM	$20M$

Table I shows the computational complexities of the algorithms. In terms of computational complexity, ILSP has $6MN+12M$, MCGM has $18M^2+32M$, SLSP-MA has $16M$, and SLSP-FM has $20M$. In comparison, the two proposed SLSP algorithms are found to be much more simple than the conventional algorithms.

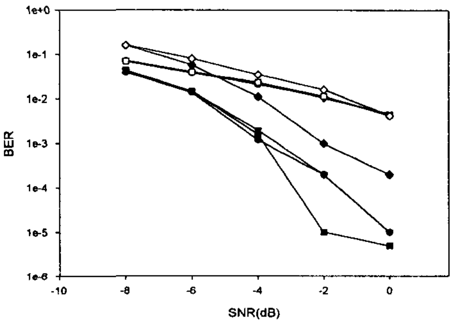

Fig. 1 BER performances as a function of SNR for ILSP, MCGM, SLSP-MA and SLSP-FM

ILSP without Rayleigh Fading
ILSP with Rayleigh Fading
SLSP-FM without Rayleigh Fading
SLSP-FM with Rayleigh Fading
SLSP-MA without Rayleigh Fading
SLSP-MA with Rayleigh Fading
MCGM without Rayleigh Fading
MCGM with Rayleigh Fading

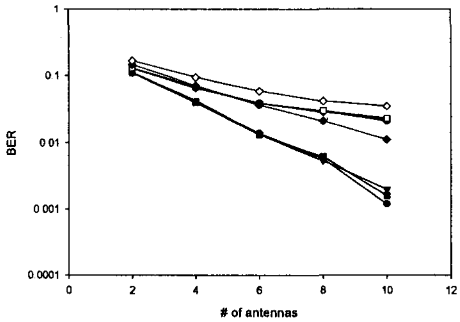

Fig. 2 BER performances as a function of number of antennas for ILSP, MCGM, SLSP-MA and SLSP-FM

ILSP without Rayleigh Fading
ILSP with Rayleigh Fading
SLSP-FM without Rayleigh Fading
SLSP-FM with Rayleigh Fading
SLSP-MA without Rayleigh Fading
SLSP-MA with Rayleigh Fading
MCGM without Rayleigh Fading
MCGM with Rayleigh Fading

VI. Conclusions

We proposed the sequential version of ILSP algorithms, SLSP-FM and SLSP-MA, with simple computational complexity of $O(M)$, unlike ILSP with relatively high computational complexity of $O(MN)$. In CDMA environments, computer simulation results show that the proposed algorithms are very competitive in the performance compared with the ILSP and MCGM.

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