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# Adaptive Algorithm based on Accumulated Signal Processing for Fast Fading Channel

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## 1. Introduction

Adaptive array antennas are being introduced to OFDM communication systems to suppress the Doppler frequency shift and increase the system capacity without increasing the transmitted power or bandwidth [1], [2]. In this paper, we propose an adaptive algorithm based on accumulated signal processing, which could be applicable to Post-FFT type OFDM adaptive array antennas. Proposed scheme calculates the weight of each element at a particular instant $t$, by considering both post and pre-received symbols. Since this technique utilizes additional future information on channel behavior to the weight calculating scheme, one can expect performance improvement with the application of the proposed algorithm in fast fading conditions. This paper also discusses the application of proposed adaptive algorithm to OFDM adaptive array. When applying to OFDM adaptive array, first, we allocate few subchannels to transmit pilot symbols. At the receiver, we perform the proposed adaptive algorithm to those pilot subchannels and interpolate the weights for the data symbols, which are allocated between the pilot symbols.

## 2. Adaptive Algorithm based on Accumulated Signal Processing

The basic structure of the proposed adaptive algorithm based on accumulated signal processing is illustrated in Fig.1. In the proposed algorithm, a certain period of received symbol stream of each antenna is accumulated once, and then the array output is calculated by performing MMSE adaptive algorithm such as SMI, RLS or LMS. When calculating the weight of each element at a particular instant $t$, a number of pre-received symbols (symbols, received after the instant $t$) as well as a number of post-received symbols (symbols, received before the instant $t$) are taken into the account. By taking this forthcoming information of the channel behavior into the weight optimizing scheme, one can expect to achieve higher accuracy than using the past information only under the calculation in fast fading conditions. In the proposed algorithm, the correlation matrix between the antennas is derived by

$$\mathbf{R}_{xx}(t) = \frac{1}{p+q+1}\sum_{i=-p}^{q} b^{|i|}\cdot \mathbf{x}(t+iT_s)\mathbf{x}^H(t+iT_s) \tag{1}$$

where, $p$ and $q$ denote the number of pre-received and post-received symbols, respectively. $b$ is the forgetting factor which is applied to give more weight to the recent data symbols. $\mathbf{x}(t)$ is the received signal vector of antenna array at $t$, given by,

$$\mathbf{x}(t) = [x_1(t), x_2(t), \cdots x_M(t)]^T \tag{2}$$

where, $T_s$ and $x_m(t)$ denote the symbol period and the received signal of the $m^{th}$ element at a particular instant $t$, respectively. The correlation vector among the reference signal and the accumulated received array signal is calculated by,

$$\mathbf{r}_{xr}(t) = \frac{1}{p+q+1}\sum_{i=-p}^{q} b^{|i|}\cdot \mathbf{x}(t+iT_s)r^*(t+iT_s) \tag{3}$$

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where $r(t)$ denotes the reference signal at a particular instant $t$. Finally the optimized weight vector of the proposed adaptive algorithm is derived by,

$$\mathbf{w}_{opt}(t) = \mathbf{R}_{xx}^{-1}(t)\mathbf{r}_{xr}(t) \qquad (4)$$

Because of using several pre-received data for the weight calculation, small data transmission delay which may be acceptable for actual communications is subject to occur. On the other hand, we can expect higher accuracy in fast fading environment. Further, the proposed algorithm will allow the adaptive array system to communicate continuously, which will enable the usage of the algorithm in both TDMA- and FDMA-based OFDM data transmission systems.

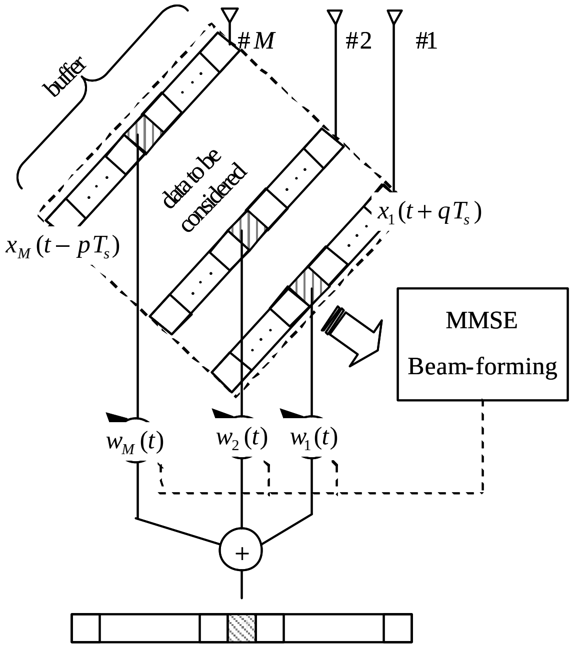


Fig.1 Adaptive algorithm based on accumulated signal processing

## 3. Simulations

### 3.1 Simulation Conditions

We have considered a propagation environment described in [3], where a number of multipath signals of both interfering and desired signals exist, with different Doppler frequency shifts, and DOAs. Considered propagation environment is shown in Fig.2 and the parameters are given in Table 1. Here $f_d$ and $L$ denote the maximum Doppler frequency shift and the number of interference signal sources, respectively.

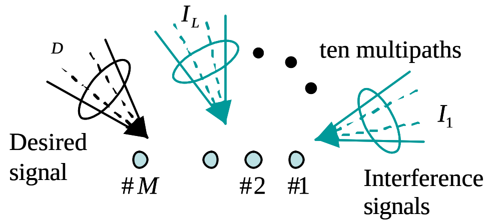


Fig.2 Simulation Environment

Table 1 Simulation environment

| | Desired | Interfering |
|---|---|---|
| Total mean power (vs. noise) | 10dB | 10dB |
| DOA (angular spread) | $30^{\circ}$ ( $5^{\circ}$ ) | $-90^{\circ}$• $90^{\circ}$ ( $5^{\circ}$ ) |
| No. of multipath | 10 | 10 each |
| Maximum Doppler ( $f_d T_s$ ) | 0.033 | |

### 3.2 Simulation Results

In the simulation, SMI adaptive algorithm was used to calculate the weight. Both pre-received symbol number $q$ and post-received symbol number $p$ were set to 10 during the simulation, namely, $(p,q)$ of $(10,10)$. Here $q=0$ corresponds to the conventional SMI, where only post-received symbols are used to calculate the weight. We have considered two types of conventional SMI algorithms with $(p,q)$ of $(10,0)$ and $(20,0)$. As a reference, results for $(0,10)$ and $(0,20)$, where only pre-received symbols are used to calculate the weight, are also being presented. System parameters are given in Table 2.

Table 2 System Parameters

| | |
|---|---|
| ~~No. of array elements ( $M$ )~~ | ~~8~~ |
| Forgetting factor ( $b$ ) | 0.9 |
| Concerned Post-symbols ( $p$ ) | 0, 10 , 20 |
| Concerned Pre-symbols ( $q$ ) | 0, 10 , 20 |
| Modulation/demodulation System | DQPSK |

To realize a quantitative analysis, we took the average SINR of hundred symbols at each time step, when measuring the temporal variation of SINR. Cumulative distribution of SINR was calculated using ten thousand symbols.

Fig.3 illustrates the temporal variation of SINR for both proposed and conventional SMI algorithm in an interference-free environment ($L=0$). Result shows that the proposed algorithm gives a better SINR comparing to the conventional algorithm.

Fig.4 shows the cumulative distribution of SINR. The simulation was done under the same interference-free environment assumed in the previous simulation. This result quantitatively verifies the betterment of the proposed algorithm.

The time variant of SINR, which was measured under five interfering ( $L=5$ ) signals arrived from the directions of $-30^\circ$, $-20^\circ$, $0^\circ$, $50^\circ$ and $80^\circ$ is illustrated in Fig.5. The cumulative distribution of SINR for the same environment is given in Fig.6. In this environment the proposed algorithm performs better too. Also it should be noted from these results that the $(20,0)$ system, which considers more post-received symbols, keeping the same number of symbols for $(10,10)$, deteriorates the system performance.

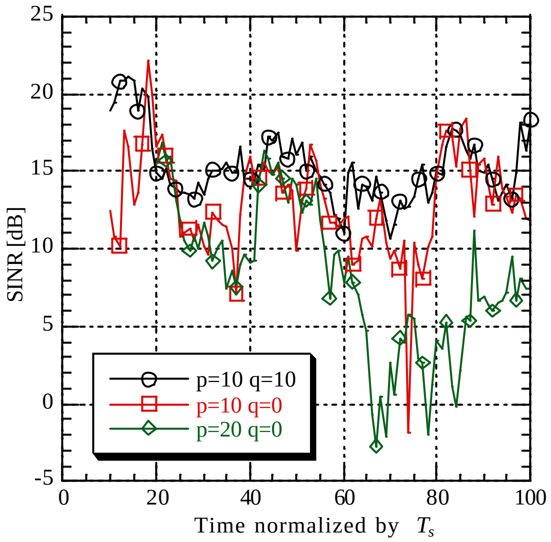


Fig.3 Time variant of SINR in an interference free environment ( $L=0$ )

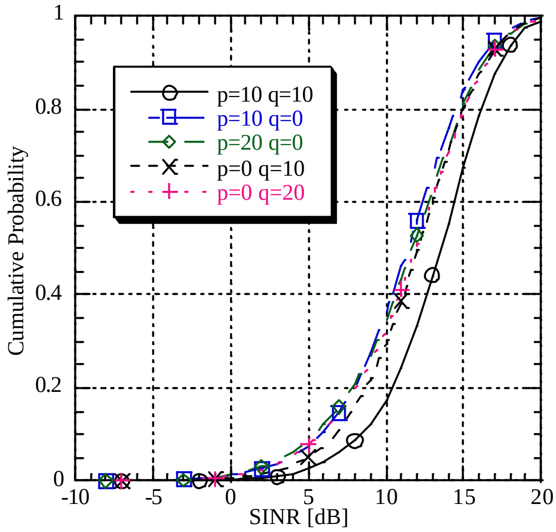


Fig.4 Cumulative distribution of SINR in an interference free environment ( $L=0$ )

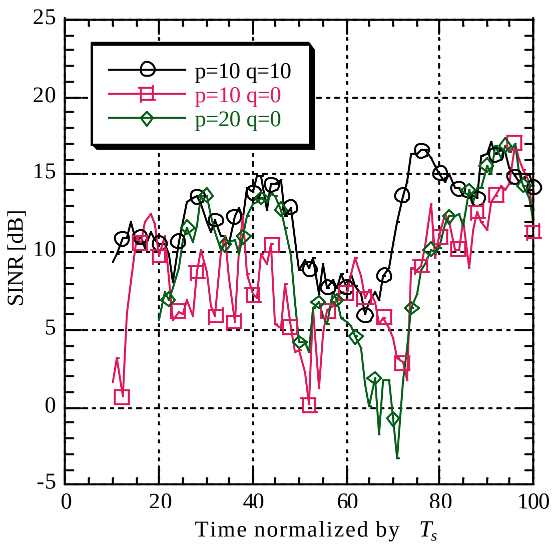


Fig.5 Time variant of SINR in an environment with five interference signals ( $L=5$ )

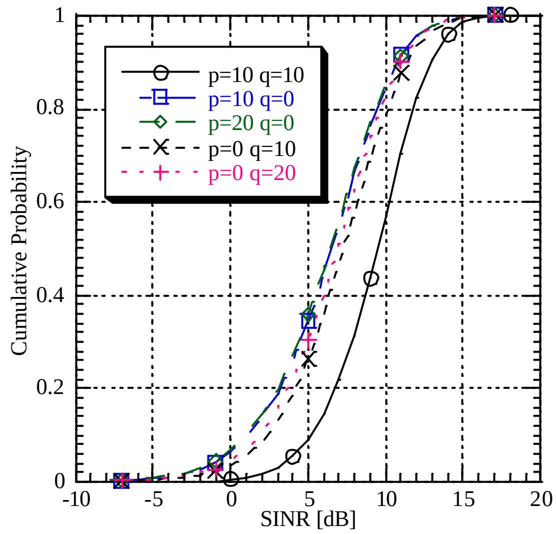


Fig.6 Cumulative distribution of SINR in an environment with five interference signals ( $L=5$ )

## 4. OFDM Application

OFDM mobile radio systems where user terminals move rapidly would be an appropriate application of our proposed algorithm since it has a large number of parallel subchannels where the obtained weights can be utilized. This will allow us to transmit a number of pilot channels and to allocate the data subchannels between those pilot channels. In the receiver, proposed adaptive algorithm will be applied to the pilot subchannels and interpolate the weights for the data subchannels using the weights of the adjacent pilot subchannels.

### 4.1 OFDM Symbol

Fig.7 illustrates the OFDM symbol, which is intended to be applied in proposed adaptive algorithm based on accumulated signal processing. As shown in the figure, a few subchannels are used as pilot channels, and a number of data subchannels are allocated between the pilot subchannels. Here $r_i^k$ denotes the $k^{th}$ reference signal of the $i^{th}$ symbol.

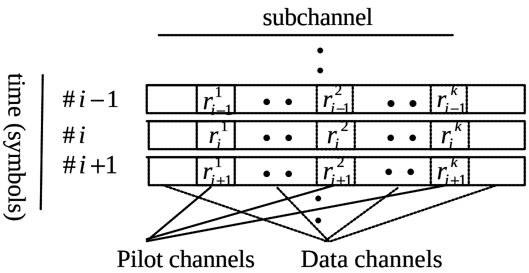


Fig.7 OFDM symbol

### 4.2 Receiving Scheme of OFDM Application

Fig.8 illustrates the receiving scheme of the proposed adaptive algorithm based on accumulated signal processing with application to OFDM system. $w_m^k(i)$ denotes the weight of the $k^{th}$ pilot subchannel of the $m^{th}$ element for $i^{th}$ OFDM symbol. In the receiver, first, we demodulate the received signal of each array element separately. Secondly we combine the array output signals by performing the proposed adaptive algorithm. Here it should be noted that we perform the proposed algorithm only to the subchannels that are used as pilot channels, and interpolate the weight vectors for the data subchannels, which are allocated between the pilot subchannels.

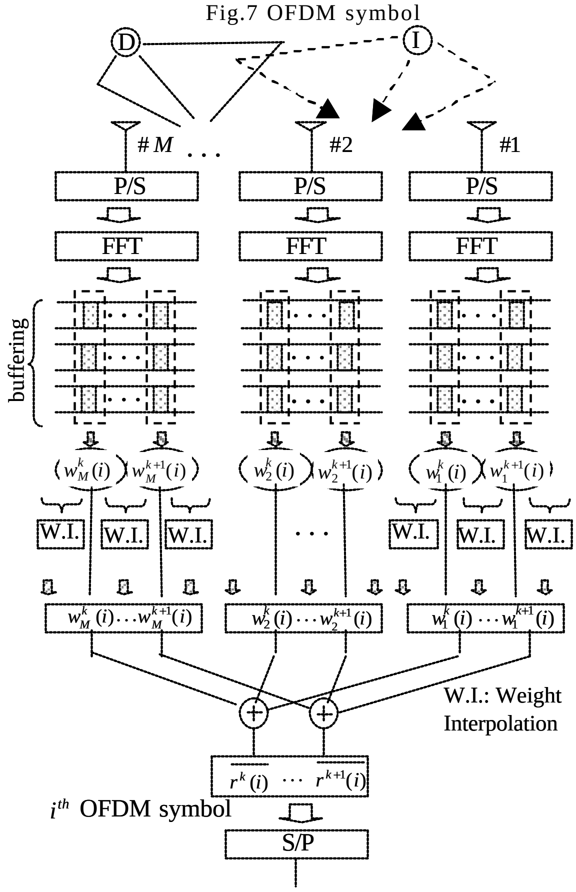


Fig.8 Receiving scheme of OFDM application

### 5. Conclusions

This paper has proposed an adaptive algorithm based on accumulated signal processing, which utilizes pre-received symbols as well as post-received symbols when calculating the weight.

It has also discussed on applying the proposed algorithm to Post-FFT type OFDM adaptive array by allocating a few subchannels as pilot channels.

By computer simulation, it was confirmed that the proposed algorithm gives a better SINR comparing to the conventional algorithms in fast fading conditions.

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