Scientific Research

# Research on Synchronization and Adaptive Resource Allocation Algorithm in MIMO-OFDM System

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**Abstract:** With the development and applications of high-speed wireless communication techniques. Orthogonal Frequency Division Multiplexing (OFDM) techniques and Multiple Input and Multiple Output (MIMO) techniques have applied in broadband wireless communication system. Using robustness of OFDM technology to multi-path effects, MIMO technology can easily be applied to broadband wireless communications. We extend the synchronization algorithms for OFDM systems to MIMO-OFDM systems and a synchronization algorithm for MIMO-OFDM systems is proposed. It has nice estimation performance and no pilots are needed. On the research of adaptive power and bits allocation scheme in MIMO-OFDM system, an adaptive resource allocation algorithm is proposed. This algorithm is simple and practical. The simulation results suggest that the algorithm has good performance.

**Keywords:** MIMO-OFDM; synchronization; adaptive modulation; resource allocation

## 1 Introduction

The next generation broadband wireless communication system[1] will be able to provide users with wireless multimedia services of high-speed wireless Internet access, wireless video, and mobile computing, which push communication technologies towards to more high-speed and more reliable. However, compared to cable channel, wireless channel is much worse. Due to multipath effects and Doppler frequency shift effects in wireless channels, there is also the angle fading. To ensure the quality of wireless communication, it is necessary to resist fading, and the primary measure to decrease fading is diversity.

Using robustness of OFDM technology to multi-path effects, MIMO technology can easily be applied to broadband wireless communications. We extend the synchronization algorithms for OFDM systems to MIMO-OFDM systems and a synchronization algorithm for MIMO-OFDM systems is proposed. It has nice estimation performance and no pilots are needed. On the research of adaptive power and bits allocation scheme in MIMO-OFDM system, an adaptive resource allocation algorithm is proposed. The simulation results suggest that the algorithm has good performance.

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## 2 Synchronization Algorithm for MIMO-OFDM System

Suppose MIMO-OFDM communications system using M-transmit antennas and N-receive antennas.

The size of FFT is $N_{fft}$ on OFDM modulation, guard interval length is $N_g$. The figure of signal transmission is shown as follow:

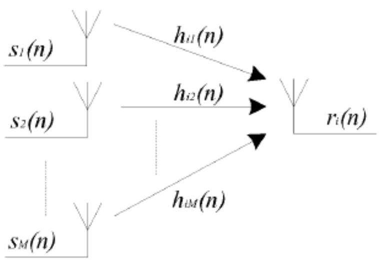


**Figure 1. Signal transmission of MIMO-OFDM communication system**

Signal $\{s_j(n), j=1,2,\mathbf{L},M\}$ received from the antenna of i aggregate through absolute multi-path channel $\{h_{ij}(n), j=1,2,\mathbf{L},M, n=0,1,\mathbf{L},L-1\}$ $\{s_j(n), j=1,2,\mathbf{L},M\}$ distribute with each other independently. Its correlation function is as follow:

$$\begin{cases} s_s^2 & t=0 \\ N_g s_s^2 \big/ N_{fft}+N_g = Ks_s^2 & t=N_{fft}, 0 \le n\%(N_{fft}+N_g) \le N_g \\ 0 & else \end{cases}$$

In order to overcome symbol crosstalk due to mult-



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ipath, it is necessary to make $N_g > L$.

We take the normalized timing error, normalized frequency offset and noise effects into account. We can get:

$$r_i(n) = e^{j(2\pi f_e n + \phi)} \sum_{j=1}^{M} \sum_{l=0}^{L-1} h_{ij}(l) S_j(n - n_e - l) + v(n)$$

Autocorrelation function of $r_i(n)$ is as follow

$$R_{r_i}(n,t) = E\{r_i(n) r_i^*(n-t)\}$$

$$R_{r_i}(n,t) = \begin{cases} \sigma_s^2 e^{j2\pi f_e t} \sum_{j=1}^{M} R_{h_{ij}}(t) + \sigma_n^2 d(t) & 0 \le t \le L-1 \\ \sigma_s^2 e^{j2\pi f_e t} \sum_{j=1}^{M} R_{h_{ij}}(t - N_{fft}) & N_{fft} \le t \le N_{fft} + L - 1 \\ & n_e \le n \le n_e + N_g \\ 0 & else \end{cases}$$

In order to improve the estimated effect, the signal of N-receive antennas can be integrated. Thus, autocorrelation function of the received signal can be defined as

$$R_{r_i}(n,t) = \sum_{i=1}^{N} R_{r_i}(n,t), \quad t = N_{fft}$$

Judgment function is $\Lambda(n_e, f_e) = \sum_{n=n_e}^{n_e+N_g-1} R_r(n, N_{fft})$, synchronizer can be constructed as follow:

$$n_e = \arg \max_{0 \le n_e \le N_{fft} + N_g} |\Lambda(n_e, f_e)|$$

$$f_e = \frac{1}{2\pi N_{fft}} angle\{\Lambda(n_e, f_e)\}$$

The synchronization range is $0 \le n_e \le N_{fft} + N_g$, $|f_e| < 1/2\pi N_{fft}$.

Computer simulations get synchronizer performance curves at different receiving SNR. Simulation system uses 4-transmit antennas and 6-receive antenna. On OFDM modulation $N_{fft} = 64$, guard interval length $N_g = 16$ is greater than the largest channel impulse response $L = 10$ .transmitted data is modulated by QPSK.

The above figure shows the average of the absolute value for estimated timing error. The upper figure shows the average of the absolute value for frequency offset estimation error. It can be concluded that the synchronizer can complete multi-path channel MIMO-OFDM communication system synchronization requirements.

## 3 Adaptive Resource Allocation Algorithm

The basic idea of adaptive modulation is to transmit power and signal by adjusting transmission power and signal bit rate, so that the SNR $E_b/N_o$ of the receiving end maintains a constant value. For multiuser MIMO-OFDM

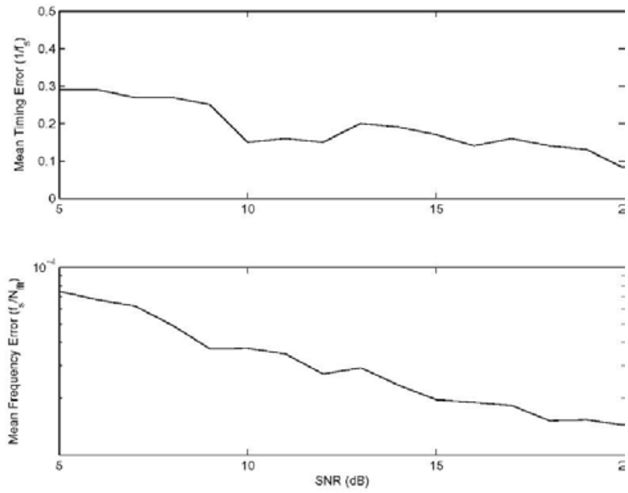


**Figure 2. Synchronizer performance curves at different receiving SNR**

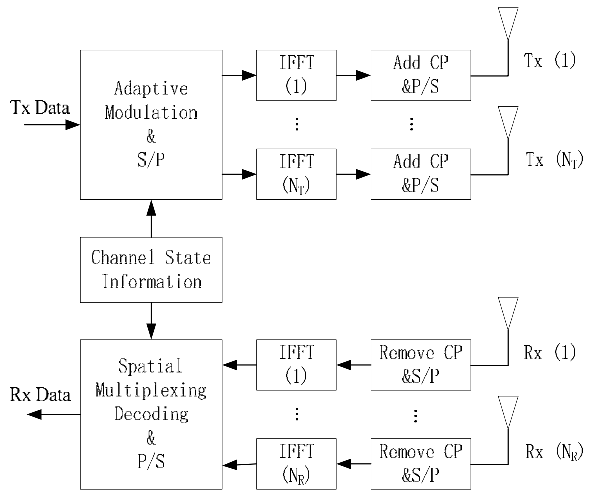


**Figure 3. Adaptive MIMO-OFDM communication system model**

communication system, it is necessary to allocate power and bits between sub-carrier and sub-channel the make sure the SNR $E_b/N_o$ constant after demodulation. As multi-user MIMO-OFDM communication system usually composes a great number of sub-channels, so the adaptive modulation scheme is more complex compared with a single receiving-transmitting antenna system [2].

This is an adaptive MIMO-OFDM system model with the transmit antennas of $N_T$ and the receive antennas of $N_R$, as figure3. The communication system adds the adaptive power and bits allocation modules, which execute adaptive bit and power allocation scheme to make system performance optimal.

We suppose that data modulation of MIMO-OFDM is MQAM, MIMO modulation and demodulation scheme adopt V-BLAST algorithm [3,4], and the signal model of subsystem n is $X_m = H_n X_m + N_n$.

As the MIMO-OFDM communication system can be considered as parallel subsystem of the number $N_C$, so V-BLAST decoding process merely apply V-BLAST decoding algorithm to various subsystems, and then merge the results. After V-BLAST decoding, the received signal demodulated by MQAM resume the transmitting information. Each subsystem can be approximately composed of space parallel channels of $N_T$, and each channel has different SNR. In case of the constellation chart size not limited, the adaptive power allocation scheme for MIMO-OFDM communication system is as follow.

AWGN channel, error bit rate of MQAM by coherent phase demodulation can be estimated by the following formula:

$$BER \le 2e^{-1.5g/(M-1)} \tag{1}$$

where γ and M represent average receiving SNR and the size of QAM constellation chart. Thus, the largest constellation chart size under the premise of given error bit rate:

$$M(g) = 1 + \frac{1.5g}{-\ln(BER/2)} \tag{2}$$

In MIMO-OFDM communication system, the receiving SNR of each sub-channel[5] is also different, even if each sub-channel is allocated the same power. One reason is the affect of fading, the other is interference between different transmit antennas.

The noise power of each sub-channel in MIMO-OFDM communication system [6] can be expressed as:

$$s_{m,n}^2 = s^2 \|W_{m,n}\|^2 \tag{3}$$

where $W_{m,n}$ is converting zero vector of the corresponding sub-channel.

Suppose that g the power allocated to sub-channel (m, n) is $S_{m,n}$, if SNR is definite, then the constellation chart size of this sub-channel of should satisfy the following qualification:

$$M_{m,n} = 1 + \frac{1.5g}{-\ln(BER/2)} \frac{S_{m,n}}{s^2 \|W_{m,n}\|^2} \tag{4}$$

where m=1, 2 … $N_T$ , n=1, 2 … $N_C$, so the spectral efficiency of system as follow:

$$SE = \frac{1}{N_c} \sum_{n=1}^{N_C} \sum_{m=1}^{N_T} \log_2\left(1 + \frac{1.5g}{-\ln(BER/2)} \frac{S_{m,n}}{s^2 \|W_{m,n}\|^2}\right) \tag{5}$$

Adaptive power allocation scheme for multiuser MIMO-OFDM communication system maximize the power under certain restrictions.

$$\sum_{n=1}^{N_C} \sum_{m=1}^{N_T} S_{m,n} = N_T N_C \overline{S} \tag{6}$$

where $\bar{S}$ represents the average transmitting power of sub-channel.

Using a similar derivation of literature 9, we can get the optimal power allocation scheme as follow:

$$S_{m,n} = \begin{cases} s^2 (C - \|W_{m,n}\|^2 / K), & \|W_{m,n}\|^2 \le CK \\ 0, & \|W_{m,n}\|^2 > CK \end{cases} \tag{7}$$

where C is determined by the following formu

$$C = \frac{\frac{N_T N_C \overline{S}}{s^2} + \sum_{n=1}^{N_c} \sum_{m=1}^{N_T} (\|W_{m,n}\|^2 / K) I(\|W_{m,n}\|^2 \le CK)}{\sum_{n=1}^{N_c} \sum_{m=1}^{N_T} I(\|W_{m,n}\|^2 \le CK)} \tag{8}$$

where

$$K = \frac{-1.5}{\ln(BER/2)}$$

$$I(x) = \begin{cases} 1, & x \text{ is true} \\ 0, & x \text{ is false} \end{cases}$$

The optimal adaptive power allocation scheme is the irrigation strategy.

First, we select a threshold value of CK. If the sub-channel equivalent power gain satisfy the condition of $1/\|W_{m,n}\|^2 < 1/CK$ , then the power is not allocated; If the sub-channel equivalent power gain satisfy the condition of $1/\|W_{m,n}\|^2 \ge 1/CK$ , then the greater $1/\|W_{m,n}\|^2$ is, the more allocated power is.

From (5) and (7), we can get the maximum spectrum utilization as follow:

$$SE = \frac{1}{N_c} \sum_{n=1}^{N_C} \sum_{m=1}^{N_T} \log_2\left(\frac{KC}{\|W_{m,n}\|^2}\right) I(\|W_{m,n}\|^2 \le CK) \tag{9}$$

Because C does not exist analytic solution, C is not explicitly given in (8).We can construct iterative algorithm by (8) to calculate accurate value of C. In most cases, the iterative algorithm can converge quickly.

## 4 Adaptive Resource Allocation Algorithm

The Adaptive resource allocation algorithm simulation



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platform was implemented under VC++6.0. The related environment and parameter settings as follows:

(1) It is utilized 4-transmit 4-receive antennas and four receiving antennas for multiuser MIMO-OFDM communication system.

(2)The data modulation is MQAM.

(3)The MIMO program is V-BLAST.

Figure 2 shows spectral efficiency of the optimal power allocation scheme as (7) under different average received SNR in 4-transmit 4-receive antennas MIMO-OFDM system[7,8].

Solid line in Figure 2 represents the Shannon boundary of adaptive modulation, which is result under the premise of limited modulation; The dot line and dash dot line represent the results when the aiming bit error rate are $10^{-3}$ and $10^{-6}$ in application of (7).

As the size of constellation is not limited, so it is only the upper bound of achieved spectral efficiency for adaptive modulation strategy in practical.

## 5 Conclusions

We extend the synchronization algorithms for OFDM systems to MIMO-OFDM systems and a synchronization algorithm for MIMO-OFDM systems is proposed. It has nice estimation performance and no pilots are needed. On the research of adaptive power and bits allocation scheme in MIMO-OFDM system, an adaptive resource allocation algorithm is proposed. This algorithm is simple and practical. The simulation results suggest that the algorithm has good performance.

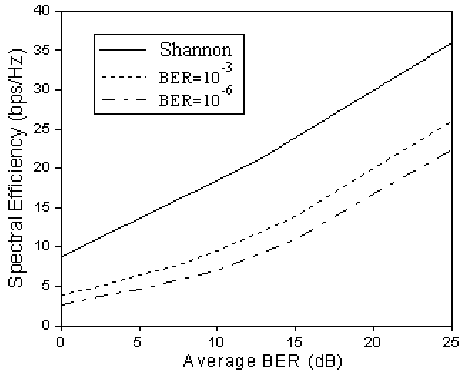


**Figure 4. The spectral efficiency of adaptive MIMO-OFDM communication system in the case of the constellation size unlimited**

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