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MIMO-OFDM adaptive array using short preamble signals

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Abstract: This letter proposes an interference cancellation method for Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing (MIMO–OFDM) adaptive array, which utilizes periodical preamble signals. A short preamble signal of IEEE802.11 based OFDM signal are mapped in only twelve subcarriers in a frequency domain and the signal in a time domain is transformed by Inverse Fast Fourier Transform (IFFT) at the transmitter. At the receiver site, the subcarriers at which only interference arrive can be found by employing Fast Fourier Transform (FFT). The propose method utilize this feature and efficiently reduce the interference by utilizing the null subcarriers which is not mapped in the short preamble signal. By a computer simulation, it is shown that the proposed method with the smaller number of training signals can obtain same Bit Error Rate (BER) performance compared to the conventional Minimum Mean Square Error (MMSE) adaptive array.

Keywords: MIMO-OFDM, adaptive array, short preamble, power inversion algorithm, null subcarrier
Classification: Antennas and Propagation

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1 Introduction

Due to the popularity of smart phone and Wi-Fi in recent wireless systems, high data transmission becomes essential with limited frequency band. Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing (MIMO–OFDM) system is incorporated into IEEE802.11.n based Wireless LAN systems [1] and Long Term Evolution (LTE) systems, because MIMO transmission can increase the data rate in proportion to the number of transmit and receive antennas [2] while eliminating the degradation on the transmission quality due to the delay signals by OFDM.

On the other hand, there are a lot of interference in unlicensed band such as 2.4 GHz band, because a lot of access point (AP) and user terminal (UT) exist inside very small local area due to its popularity and convenience for usage. Moreover, there is interference by microwave oven at 2.4 GHz. Hence, MIMO-OFDM transmission must be employed while reducing such interference. It is well known that an adaptive array can suppress the interference [3]. However, there is a issue that the number of training signals is a very few when considering conventional adaptive array using Minimum Mean Square Error (MMSE) criteria.

In this letter, we propose an interference cancellation method for MIMO-OFDM adaptive array, which utilizes periodical preamble signal. The signals are mapped in only twelve subcarriers in short preamble signals of IEEE802.11 based OFDM signals [1] and the signal in a time domain is transformed by Inverse Fast Fourier Transform (IFFT) at the transmitter. At the receiver site, the subcarriers at which only interference arrive can be detected by employing Fast Fourier Transform (FFT). The propose method utilizes this feature and efficiently reduce the interference. The idea using null subcarriers for the interference cancellation have been already proposed in [4, 5, 6]. However, null subcarriers are very few when considering OFDM signals for the communication [1]. On the other hand, all the subcarriers except twelve subcarriers for the short preamble signal can be utilized for the interference reduction in the proposed method. By a computer simulation, it is shown that the proposed method with the smaller number of training signals can obtain same Bit Error Rate (BER) performance compared to the conventional Minimum Mean Square Error (MMSE) adaptive array.

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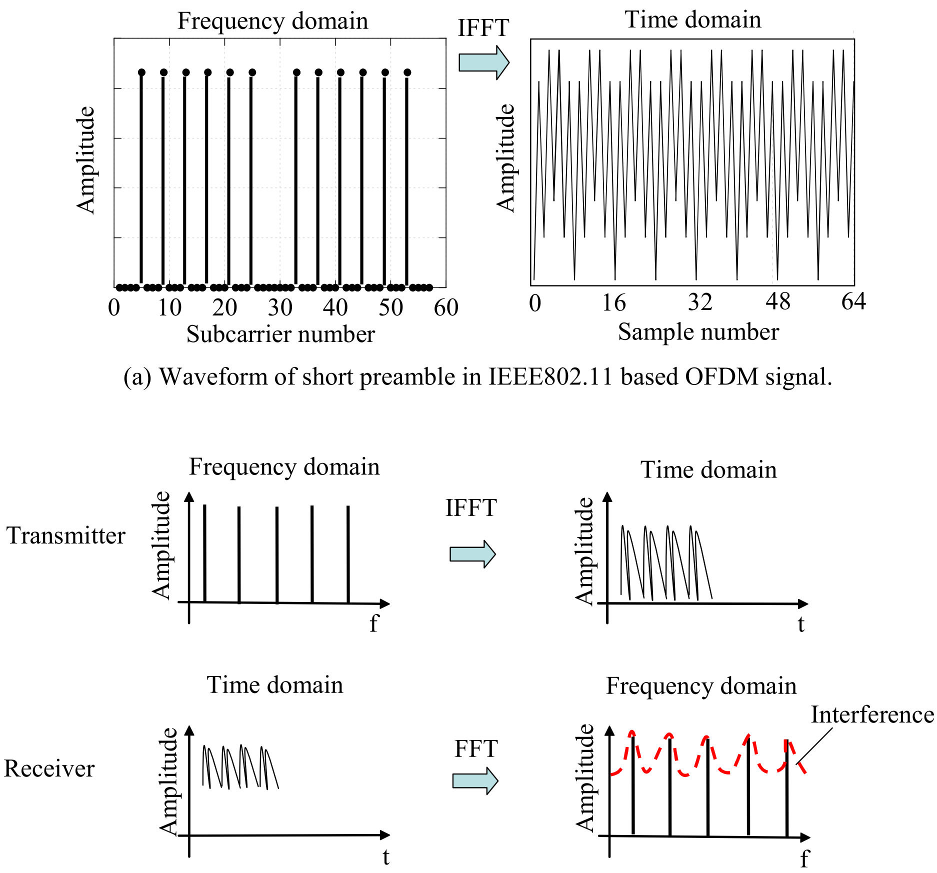

(a) Waveform of short preamble in IEEE802.11 based OFDM signal.

(b) Relationship between desired signal and interference in short preamble.

Fig. 1. Idea for detecting interference.

2 Proposed method

Fig. 1 shows a waveform of short preamble signal in IEEE802.11 based OFDM signal and relationship between the desired signal and interference in the short preamble signal at the transmitter and receiver. As shown in Fig. 1 (a), the QPSK signals are mapped at only twelve subcarriers and this signal is transformed to the signal in the time domain by using Inversed Fast Fourier Transform (IFFT) at the transmitter. As shown in Fig. 1 (a), the signal by the IFFT is a periodical signal and same signal is repeated on every eight sample.

Fig. 1 (b) shows a key point to detect *only* interference. When the interference is arrived at the receiver, *only interference* appears at the subcarriers except the subcarriers which are mapped for the short preamble signal in the frequency domain at the receiver. Since the short preamble signal is used for a timing detection in the time domain, the FFT is not required for the short preamble signal when considering an actual OFDM transmission. However, FFT calculation is easily realized for the detection of interference because the circuit of FFT processing has been already implemented in the OFDM modem. The proposed method focuses on the interference which appears at the subcarriers except the subcarriers for the short preamble signals.

Fig. 2 shows the configuration the receivers when applying the proposed method. N and K denote the number of receive antennas and subcarriers,

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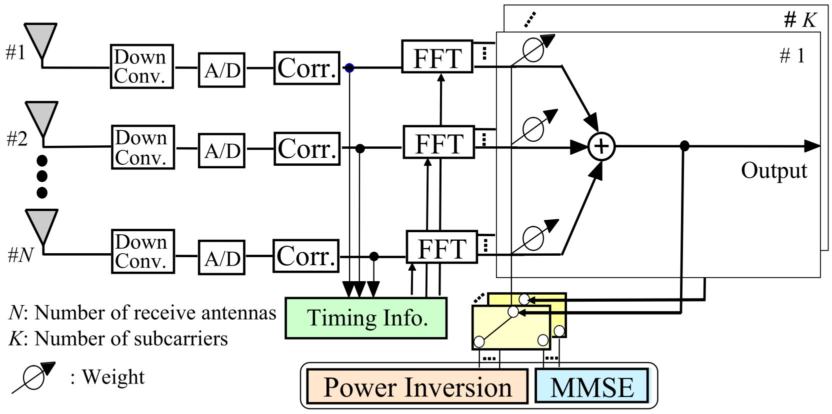

Fig. 2. Configuration of receiver by proposed method.

respectively, in Fig. 2. In the proposed method, the timing detection is employed by using the short preamble signals and received signals in the time domain. When $s_p(t)$ and $x(t)$ denote the short preamble and received signals, respectively, the correlation value, ρ is given by

$$\rho = \frac{\left|\sum_{t=1}^{L} s_p(t)^* x(t)\right|}{\sqrt{\sum_{t=1}^{L} |s_p(t)|^2}\sqrt{\sum_{t=1}^{L} |x(t)|^2}}, \tag{1}$$

where L is the number of samples for the correlation calculation and $L = 160$ in the IEEE802.11 based OFDM signals. By using the calculation of ρ, the head of data packet can be obtained.

Next, FFT processing is employed by using the result of the correlation calculation. After the FFT processing, only interference plus noise appear when the interference arrives as shown in Fig. 1 (b). In the proposed method, the power inversion algorithm [7] is employed for null subcarriers. The power inversion algorithm can suppress all the signals within a degree of freedom on the array antenna and this algorithm is suitable for reducing the interference on the null subcarrier. On the other hand, the number of samples is limited on the OFDM signals, the following method is used to obtain the weight by power inversion algorithm.

$$\boldsymbol{W}(m+1) = \boldsymbol{W}(m) + \mu\,[\boldsymbol{S} - \boldsymbol{X}(m)y^*(m)] \tag{2}$$

$$\boldsymbol{X}(m) = [x_1(m), \cdots, x_N(m)]^T \tag{3}$$

$$\boldsymbol{W}(m) = [w_1(m), \cdots, w_N(m)]^T \tag{4}$$

$$y(m) = \boldsymbol{W}^H(m)\boldsymbol{X} \tag{5}$$

Here, $\boldsymbol{X}(m)$ and $\boldsymbol{W}(m)$ denote the received signal and weight vectors at m-th iteration in the frequency domain. $y(m)$ is the output signal after interference cancellation at m-th iteration in the frequency domain. $\boldsymbol{S}$ is adjusted so that $\boldsymbol{W}(m)$ does not become $[0, \cdots, 0]^T$. In this paper, $\boldsymbol{S}$ is set to be $[1, \cdots, 0]^T$.

In the subcarriers which are mapped for the short preamble, MMSE algorithm is applied, because the receiver obtains *a prior* information regarding

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modulation signals for the short preamble. Recursive Least Square (RLS) is employed for the calculation of MMSE. The weight update is as follows:

$$\boldsymbol{W}(m+1) = \boldsymbol{W}(m) + k(m+1)\epsilon^*(m+1) \tag{6}$$

$$k(m) = \frac{\alpha^{-1}R_{xx}^{-1}(m-1)\boldsymbol{X}(m)}{1+\alpha^{-1}\boldsymbol{X}^H(m)R_{xx}^{-1}(m-1)\boldsymbol{X}(m)} \tag{7}$$

$$\epsilon(m) = s_p(m) - \boldsymbol{W}^H(m-1)\boldsymbol{X}(m) \tag{8}$$

$$R_{xx}^{-1}(0) = \delta\boldsymbol{I} \tag{9}$$

where $\boldsymbol{I}$ is the identity matrix and δ is set to be 0.01 in this paper.

After the transmission using the short preamble, the long preamble for a channel estimation is transmitted. Since the known signal information in the long preamble is obtained, RLS algorithm is employed for all the subcarriers. Note that the interference can be suppressed thanks to the adaptive algorithm during the period of short preamble signals.

3 Effectiveness of the proposed method

In order to clarify the effectiveness of the proposed method, we employed the computer simulation using IEEE802.11n based OFDM signals. We assume independent and identically distributed (i.i.d.) flat Rayleigh fading to exam the basic performance of the proposed method. 2-data streams are transmitted from the UT as the desired signals. We assume one interference source. The number of antennas at the AP is three. The trial number is 1,000 for the different propagation channels and 10,000 bit are generated for each trial. The modulation scheme is QPSK for both desired signals and interference.

As shown in Fig. 1, short preamble is repeated every eight symbols. On the other hand, 2-OFDM symbols (160 samples) are used for the short preamble signals and 64 points are required for the FFT. To obtain larger number of samples for the weight calculation by the proposed method, the received signals on the sample numbers of 1∼64, 17∼80, $\cdots$, 97∼160 are used in the proposed method when the FFT processing is employed. By doing this processing, the number of FFTs becomes six.

Fig. 3 shows Signal to Interference plus Noise power Ratio (SINR) and BER characteristics. As shown in Fig. 3 (a), the SINR is greater than 20 dB with only 4 iterations, because the power inversion algorithm is employed for only interfering signal. Hence, the sufficient SINR can be obtained when the number of training signal is six.

As can be seen in Fig. 3 (b), the BER cannot be improved without adaptive processing even when the SNR becomes higher. On the other hand, almost same performance by the proposed method is obtained compared with Winner solution by MMSE algorithm. Hence, it is shown that the proposed method obtains the ideal performance with the aid of interference cancellation by using null subcarriers in the short preamble signal.

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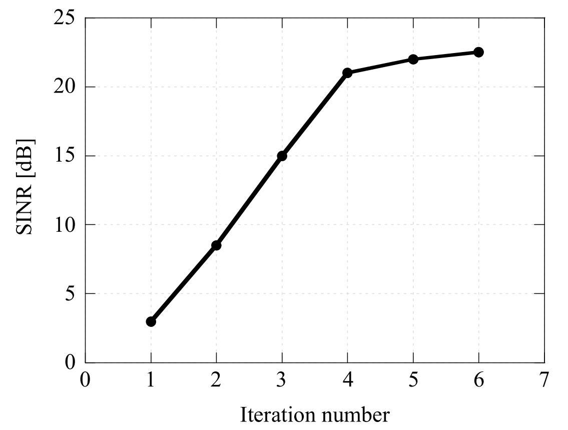
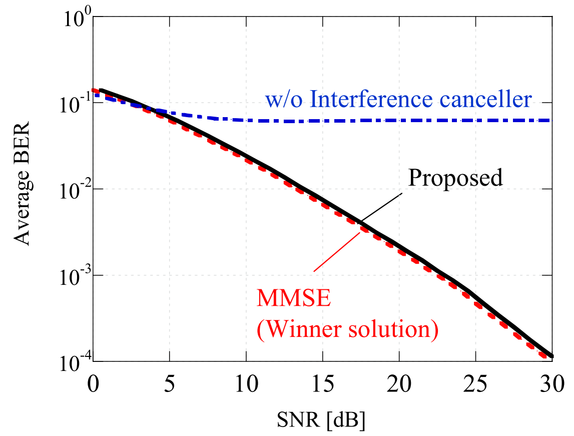


(a) SINR versus iteration number



(b) Bit error rate versus SNR

Fig. 3. SINR and BER characteristics.

4 Conclusion

This letter proposed an interference cancellation method for MIMO-OFDM adaptive array, which utilizes periodical preamble signals in a frequency domain. We utilized the null carriers in short preamble signal of IEEE802.11 based OFDM signals and the power inversion algorithm is employed in these null subcarriers when the interference arrives. By the computer simulation using IEEE802.11 based OFDM signals, it is shown that the proposed method with the smaller number of training signals can obtain same BER performance compared to the conventional MMSE adaptive array.

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