Interference detection for other systems using MIMO-OFDM signals

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***Abstract*—This paper proposes an interference detection method in MIMO transmission, which utilizes periodical preamble signals in a frequency domain. In this paper, we assume the collision between the short preamble signal in WLAN system and interfering signal like a microwave oven. In the propose method, second antenna receives the signals while first antenna transmits the preamble signals. Hence, the interference can be detected by observing the subcarriers which are not mapped short preamble signal using the received signal after the FFT processing. Moreover, we utilize the dual polarized antennas to reduce the mutual coupling between the transmitter and receiver. By a computer simulation and measurement with the use of orthogonal polarized antenna, it is shown that the proposed method can successfully detect interference from the other system when the interfering power is greater than the noise power.**

***Index Terms*—MIMO, collision detection, short preamble signals, orthogonal polarized antenna**

I. Introduction

Recently, wireless LAN (WLAN) devices are equipped in many user terminals (UT). Therefore, access points (APs) of WLAN are widely introduced at offices and houses. The interference can be reduced to some extent thanks to the carrier sense [1]. However, the collision occurs between the WLAN devices with IEEE802.11b/g/n standard and products such as microwave oven at 2.4 GHz band. In wired LAN, an access control scheme called carrier sense multiple access/collision detection (CSMA/CD) is introduced [2]. The wired LAN can detect the packet collision by the voltage variation inside the Ethernet cable before packet transmission. Since the wired LAN employs packet contention detection in advance and re-transmission immediately, transmission efficiency is over 90% [3]. On the other hand, the access control method called CSMA/collision avoidance (CSMA/CA) is adopted in WLAN [1]. Unlike wired LAN, it is difficult to detect the packet collision when the signals are transmitted. Hence, the reception characteristic is judged by the reply of acknowledgement (ACK) by a receiving station. Compared to the wired LAN, the transmission efficiency of WLAN is very small and its value is less than 65 %, because the re-transmission cannot be employed when the collision occurs [3]. Hence, the interference detection when the transmission is employed is one of key issues for high efficient communication.

This letter proposes a interference detection method using multiple-input multiple-output (MIMO) transmission [5]. The proposed method utilizes the fact that the second antenna is idle when the first antenna transmit the short preamble signals which are used for timing synchronization with the UT. The signals are mapped in only several subcarriers in short preamble signals of IEEE802.11 based OFDM signals and the signal in a time domain is transformed by IFFT at the transmitter. At the receiver, the correlation calculation is employed and period of the short preamble signals is detected. Conventionally, the signal is discarded after the timing synchronization. On the other hand, in the proposed method, the received signals are transformed in the frequency domain by the FFT processing. The interference can be detected by observing the subcarriers which are not mapped short preamble signal using the received signal after the FFT processing. By a computer simulation, it is shown that the propose method can successfully detect interference from the other system. Moreover, we propose the use of dual polarized antennas at the AP and its coupling characteristic is evaluated.

The remainder of this paper is organized as follows. Section II shows the proposed method using the short preamble in MIMO transmission is explained. Section III shows effectiveness of the proposed method by computer simulation and measurement.

II. Proposed method

Fig. 1 shows the frame format when applying the proposed method. This format is used in IEEE802.11n based WLAN system. Fig. 2 shows the waveform of short preamble at the transmitter and receiver to show the interference detection using short preamble signals. The system configuration by the proposed method is shown in Fig. 3. In the IEEE802.11a/g/n based WLAN system, short and long preamble signals are used the timing synchronization and the estimation of channel state information (CSI) between the AP and UT, respectively.

In the proposed method, we assume 2$\times$2 MIMO transmission. As can be seen in Figs. 2, the first antenna (Antenna #1) transmits the short preamble signals to the UT. As shown in Fig. 1, we utilize the fact that the short preamble signals are transmitted by only Antenna #1. Hence, there is an opportunity for a second antenna (Antenna #2) to receive the short preamble signals when the transmission by the Antenna #1 to the UT is employed. When the collision arises, the interference arrives at the Antenna #2 when the the Antenna #1 transmits the signals to UT.

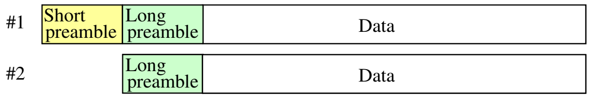


Fig. 1. Flame format of WLAN signals.

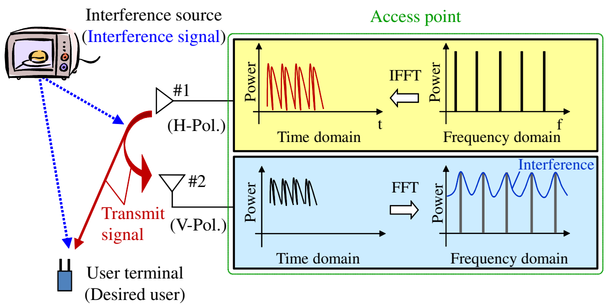


Fig. 2. Waveform of short preamble at transmitter and receiver.

Since the power of desired signal from Antenna #1 to #2 is much larger than that of interference from IS to AP, the isolation is required between Antenna#1 and #2. In this paper, there are following features in the proposed configuration and method.

(A) Isolation between Antennas #1 and #2 by using dual polarized antennas.

(B) Interference detection using received signal after the FFT processing.

As for feature (A), simultaneous transmission (by Antenna #1) and reception (by Antenna #2) using dual polarized antennas is proposed. The dual polarized antennas are generally used for reducing the spatial correlation between two antennas and especially effective in outdoor scenario [5], when the MIMO systems are considered. In the proposed method, the dual polarized antennas are used not only the reduction on the spatial correlation but also the isolation for simultaneous transmission and reception. The basic performance in an actual room is evaluated in Section III.

Regarding the detailed feature of (B), the principle is explained hereafter. Fig. 2 shows the waveform of short preamble at the transmitter and the received signal at the receiver to

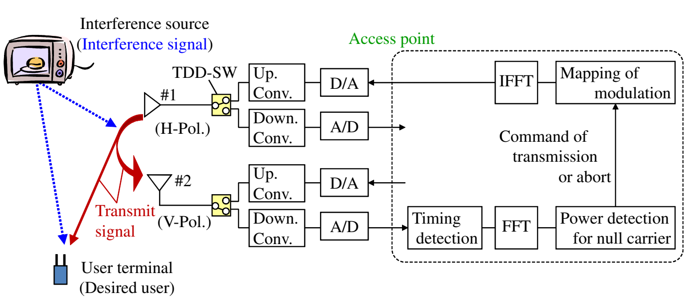


Fig. 3. System configuration by proposed method.

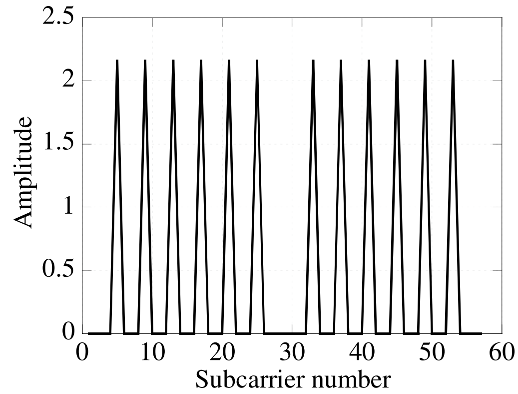


Fig. 4. Amplitude of short preamble signal in the frequency domain.

show interference detection using short preamble signals. As can be seen Fig. 2, the short preamble signal is adopted in IEEE802.11a/n/g based WLAN system. Fig. 4 shows the amplitude of short preamble signal in the frequency domain [1]. As shown in Fig. 4, only twelve signals are mapped. At the transmitter, the signals are mapped for only twelve subcarriers to generate the periodical signal in time domain [1]. The signal is transmitted after the IFFT processing. At the receiver, the timing synchronization between the known transmit and received signals is employed.

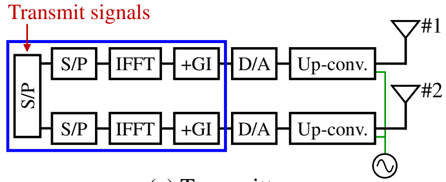
At the receiver, the timing synchronization between the known transmit and received signals is employed. The timing synchronization is realized by using the correlation calculation between the received signal, $y(t)$ and $s_p(t)$ which is the short preamble signal in time domain. The correlation value, ρ is denoted as

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

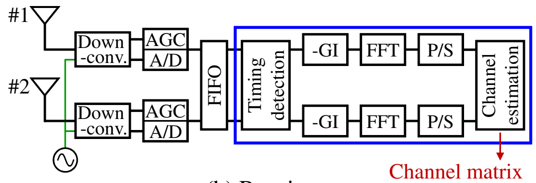
where L is the number of symbols that the correlation calculation is employed and $L = 160$ in IEEE802.11n based OFDM signal. The correlation value, ρ is maximized at the initial timing of the short preamble signals.

In the general WLAN system, the short preamble is not used after the timing synchronization. In this paper, we utilize the short preamble signals after the FFT processing. The received signals after the FFT processing contain the desired signal, interference signal and noise. Interference plus thermal noise can be detected by observing the subcarriers which are not mapped short preamble signal using the received signal after the FFT processing. When the interference power is greater than the noise power, the arrival of interference can be judged by checking the power on the subcarriers which are not mapped short preamble signal. The noise power is used as the threshold value. The noise power can be estimated by power on the subcarriers that the signals are not mapped at the transmitter.

Finally, as can be seen Fig. 3, the transmitter stops com-



(a) Transmitter.



(b) Receiver.

Fig. 5. MIMO-OFDM transceiver.

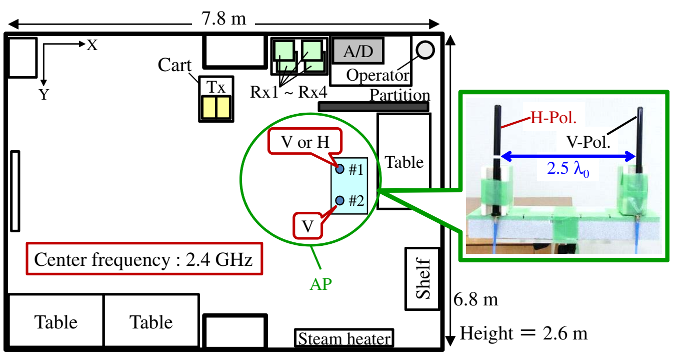


Fig. 6. Measurement environment for mutual coupling effect.

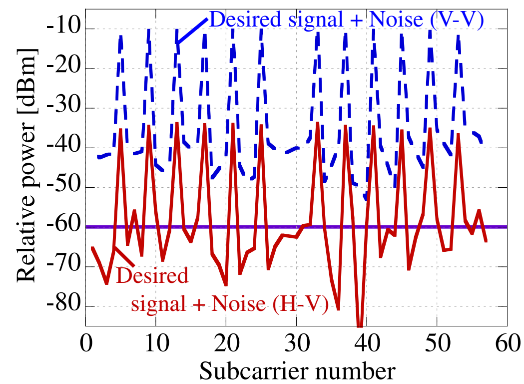


Fig. 7. Received power in frequency domain (Measurement results).

TABLE I
SIMULATION PARAMETERS

Desired/Interfering signal	1
SNR	30
SIR average	10-40
The number of rays	100
Propagation path of interference	Rayleigh
number of receive antenna	1
Bandwidth	20MHz
number of FFT points	64
Communication for the number of subcarriers	56
Pilot subcarrier number	4
GI length	16
OFDM symbol length	80
short preamble length	2OFDM symbol
lomg preamble length	2OFDM symbol
pilot subcarrier number	6, 20, 34, 48

municating with UT. Since the proposed method do not need ACK signal unlike CSMA/CA, we confirmed that the transmit efficiency becomes very high and the transmit efficiency by the proposed method is approximately 90% [3].

III. EFFECTIVENESS OF PROPOSED METHOD

Figs. 5 and 6 show MIMO-OFDM transceiver and the measurement environment for mutual coupling effect, respectively. IEEE802.11n based MIMO-OFDM signals can be transmitted and received by the transceiver in Fig. 5(a) and (b) [6]. As shown in Fig. 6, vertical polarized or dual polarized antennas for the transmit and receive antennas are used for the measurement of mutual coupling. The AP is located at the place in Fig. 6. The center frequency is 2.4 GHz. The element spacing is set to be 2.5 λ_0. The transmit power is 0 dBm and the average noise power was -60 dBm.

Fig. 7 shows the measured received power when the short preamble signals are transmitted by actual IEEE802.11n based OFDM signals [6]. The transmit antennas are vertical and horizontal polarized antennas, respectively. The received antenna is vertical polarized antenna. As can be seen in Fig. 7, the power reduction is approximately 10 dB when using vertical polarized antennas due to high mutual coupling. Moreover, the noise power is increased due to the saturation of low noise amplifier at the receiver. On the other hand, 35 dB power reduction can be observed and noise power is not increased when using dual polarized antennas. Hence, it is shown that the use of dual polarized antennas is effective for the proposed interference detection. In order to clarify the basic characteristics of the interference detection by the proposed method, the computer simulation using IEEE802.11n based OFDM signals is employed. The simulation parameters are shown in Table III. The signal to noise power ratio (SNR) is set to be 30 dB and signal to interference power ratio (SIR) is set to be 10 and 40 dB. Since the transmit and receive antenna are closely located with each other, the propagation characteristic of desired signal is assumed be the AWGN channel. The Rayleigh fading is assumed as the propagation channel on the interference by the UT. The other basic parameters are the same with IEEE802.11n standard.

Figs. 8(a) and (b) show the received power in the frequency domain. The solid lines are received powers and the broken lines are the powers of desired signal plus thermal noise. As can be seen Fig. 8(a), it is possible to judge the interference, because the signals can be detected at the null subcarriers. On the other hand, Fig. 8(b) indicates that the interference is hidden in the thermal noise. Therefore, it is shown that the

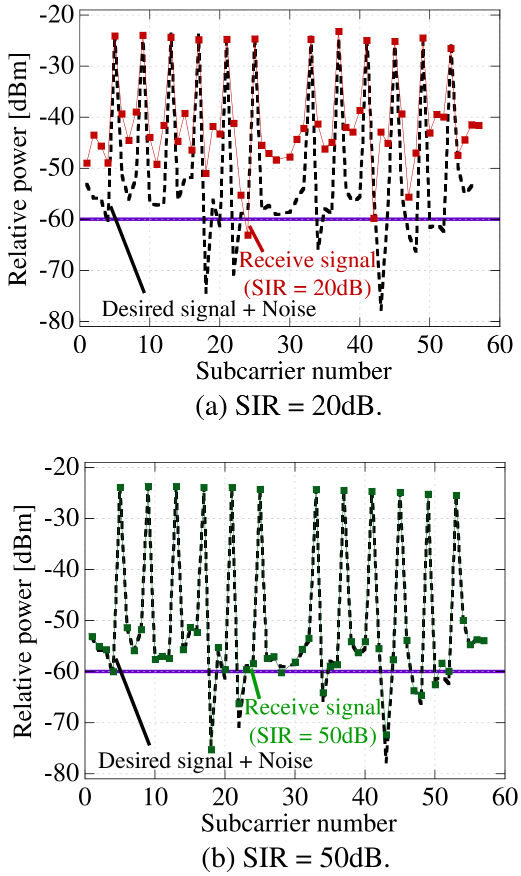


Fig. 8. interference signal power estimated from the receive signal.

interference can be sufficiently detected when the interference power is greater than the noise power. In the future, we will conduct the measurement regarding the interference detection by using the testbed in [6].

IV. Conclusion

This paper has proposed the interference detection method by utilizing the short preamble signals in the MIMO transmission. The proposed method focuses on IEEE802.11 based short preamble signals which are mapped at only twelve subcarriers in the frequency domain and the simultaneous transmission between transmitter and receiver. By the proposed method, it was shown that the interference from the other system can be detected by observing the null subcarriers which are not mapped the desired signals after the FFT processing. By the measurement using the dual polarized antennas, over 35 dB isolation was obtained. Moreover, it was found that the interference can be detected when the interference power is greater than the noise power via the computer simulation.

Acknowledgement

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