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Comparison of 4×1 SIMO and 2×2 MIMO sensors based on measured propagation channels

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1 Introduction

High-speed transmission technologies using array signal processing such as Single Input Multiple Output/ Multiple Input Multiple Output (SIMO/MIMO) have been recently attracted much attention due to smart phones and wireless LAN systems. High data transmission can be realized by utilizing accurate channel state information (CSI). However, it is well known that the characteristic of SIMO/MIMO performance is severely degraded by variation of the propagation channel [1].

In this paper, we take advantage of the feature that the achievable bit rate of SIMO/MIMO transmission is degraded in the time variant channel[1]. An indoor intruder detection method using the SIMO channel is proposed [2]. We proposed an intruder detection method which utilizes channel matrix in Multiple Input Multiple Output (MIMO) channels [3], in order to enhance detection performance in [2]. We call this method as MIMO Sensor.

In this paper we evaluate the detection performance of SIMO/MIMO sensors which have same number of channel responses. : 4×1 SIMO and 2×2 MIMO. 2×2 MIMO sensors is shown to be effective compared to 4×1 SIMO sensor when the element spacing is very narrow. It is verified that the detection probability by SIMO sensor is affected by position of transmit antennas and measurement courses while the performance is not changed by MIMO sensor regardless of measured courses.

2 Proposed method

Figure 1 shows the principle of MIMO sensor. Figure 1(a) and (b) represent the variation of channel matrix in MIMO channel due to a person. Although the channel capacity on the MIMO transmission is severely degraded in time variant channels [1], we utilize the variation of channel matrix in MIMO channel as an input of sensor. When M and N are the number of transmitting and receiving antenna, the channel matrix $\boldsymbol{H} \in C^{N\times M}$is change to $\boldsymbol{H'} \in C^{N\times M}$due to the intrusion by the person. We realize the intrusion detection by checking the variation of the channel matrix, $\boldsymbol{H}$. The variation of the channel matrix can be expressed by time correlation function. Let us assume that $h_{no,ij}$ $(i = 1 \sim N, j = 1 \sim M)$ is a component at the channel matrix without people in the room. When $h_{ij}(t)$ is a component of the channel

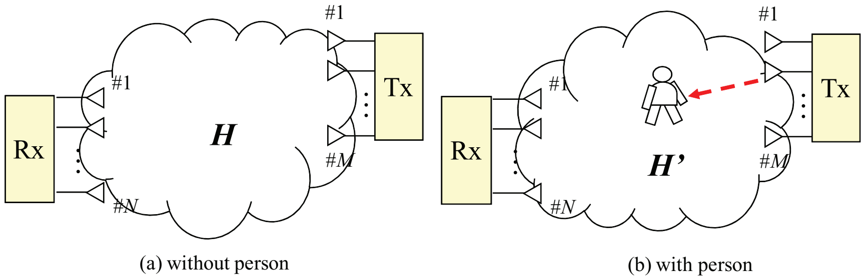

Figure 1: Principle of MIMO sensor

matrix on time t, the time correlation, $\rho_H(t)$ is represented by

$$\rho_H(t) = \frac{\left|\sum_{i=1}^{N}\sum_{j=1}^{M} h^*_{no,ij} h_{ij}(t)\right|}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{M} |h_{no,ij}|^2}\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{M} |h_{ij}(t)|^2}}. \tag{1}$$

We use this variation of correlation as valuation functionDIn a Eqn.(1), if $M = 1$, it can use as a correlation value in a SIMO sensor.

We compute a threshold for every measurement. A threshold is computed using the average value of the measured result. The detailed calculation method for the threshold values is shown in [3].

3 Measurement environment

To clarify the diversity effect on the transmit and receive sites in SIMO/MIMO sensors, we conducted the measurement in an actual indoor environment. The measurement environment is shown in Figure 2. The size of room is $8.9\times15.8\times2.6$ m (140m^2) in X, Y and Z planes. The number of transmit and receive antennas are two and four, respectively: 4×2 MIMO channel measurement can be realized. The frequency band is 440 MHz.

The antenna configuration used by this measurement is shown in Table1. When using 2x2 MIMO case, received antennas 1 and 4 are used. When 4×1SIMO is considered, the transmit antenna 1 and 2 are used as SIMO(1) and SIMO(2), respectively.

The print dipole antenna, which is known as omni-directional antenna in the horizontal plane, is used for transmit and receive antennas. As shown in Figure 2, the MIMO channels are measured when a person moves on Course A, B, C, D, E and F. The total measurement time was 12 seconds for courses A to D and 8 seconds for courses E and F, respectively. The number of person for the measurement was two and their body height was approximately 170 cm. The antenna positions for

Table 1: Antenna configurations.

	TX1	TX2	RX1	RX2	RX3	RX4
MIMO	○	○	○			○
SIMO (1)	○		○	○	○	○
SIMO (2)		○	○	○	○	○

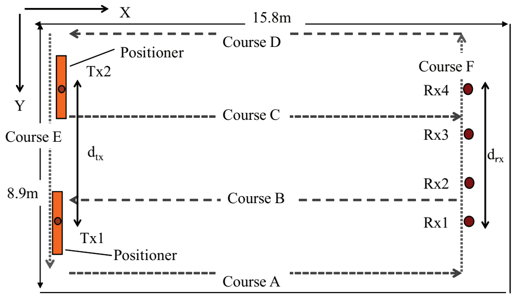

Figure 2: Measurement environment

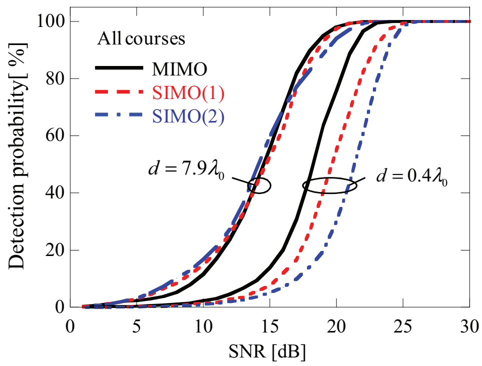

Figure 3: Detection probability vs. SNR.

Tx and Rx in this measurement are shown in Figure 2. The array width d_{Tx} and d_{Rx} at the transmitter and receiver sites are set to be 0.4, 2.7, 4.0, 5.3, 6.6, 7.9 λ_0, respectively. $d = d_{\mathrm{Tx}} = d_{\mathrm{Rx}}$. The position of receive antenna were moved 10 times with the interval of 6.25 cm by using a position controller. The antenna height at Tx and Rx sites are set to be 1.0 m.

We use OFDM (Orthogonal Frequency Division Duplexing) signal which is incorporated in Wireless LAN (W-LAN) systems [4]. Timing presumption and channel presumption are realized using the short preamble of an IEEE802.11n standard, and a long preamble, respectively. In this measurement, bandwidth is set to 6.25 MHz. The number of sub-carriers is 56. Moreover, a propagation channel is acquirable at 0.152 ms intervals.

4 Intruder detection performance by SIMO/MIMO sensor

Figure 3 compare the detection probability when considering SIMO ($(M, N) = (1, 4)$) and MIMO ($(M, N) = (2, 2)$) sensors. The results with all courses are plotted in Figure 3. The results with $d = 0.4, 7.9\lambda_0$ are plotted. The noise power is given so that the average SNR is 30 dB when the transmit power with $d = 0.26$ m is –13 dBm. Hence, the difference in received power due to antenna width, measured course and antenna height can be evaluated. Note that the difference among MIMO, SIMO (1), and SIMO (2) sensors can be referred in Table 1. As can be seen in Figure 3, the detection performance by MIMO sensor is almost same with that by SIMO sensor when $d = 7.9\lambda_0$. On the other hand, the detection probability of MIMO is much higher than that of SIMO(1)/SIMO(2) when $d = 0.4\lambda_0$. Moreover, it is clarified that the detection probability is improved by using wider antenna width regardless of antenna configuration (MIMO/SIMO(1)/SIMO(2)).

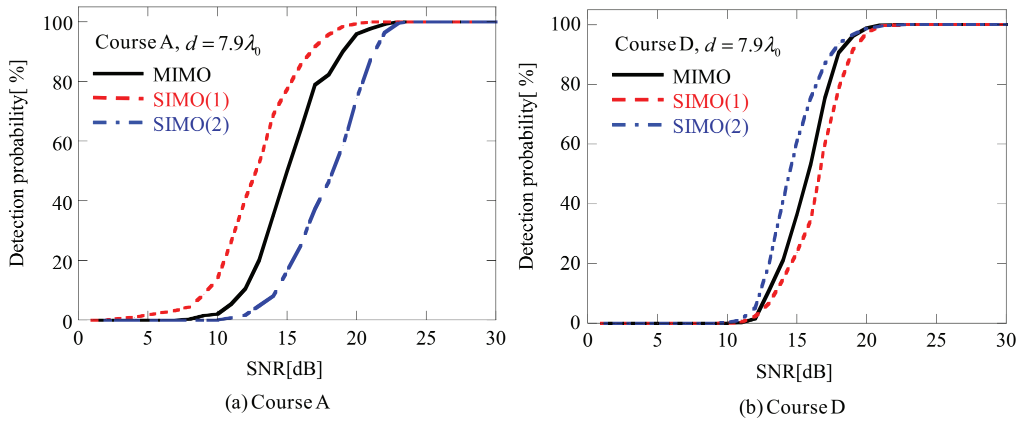

Figure 4: Detection probability vs. SNR when courses A and D are considered ($d = 7.9[\lambda]$).

Figure 4 denotes the detection probability versus SNR when courses A and D are considered. The array width is 7.9 λ_0. As can be seen in Figure 4(a), it is shown that the detection performance by SIMO (1) is much higher than that by SIMO (2). On the other hand, as can be seen in Figure 4(b), we confirm that the detection probability by SIMO (1) is lower than that by SIMO (2). Although the detection probability by SIMO is greatly affected by the antenna position at the transmitter site and measurement courses, the detection probability of MIMO is not changed regardless of measurement courses by transmit and receive diversity effects.

5 CONCLUSION

In this paper, we compared the detection performance of SIMO/MIMO sensors which have same number of channel responses at a large room (140m^2): 4×1 SIMO and 2×2 MIMO. It is shown that the detection probability by 4×1 SIMO sensor might be degraded due to single antenna at the transmitter site while 2×2 MIMO sensor obtains the high detection probability by both transmit and receive diversity effects.

References

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