

# Basic study on human detection by MIMO sensor with antennas at ceiling and floor

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**Abstract** - Multiple Input Multiple Output (MIMO) sensor, which is utilized for intruder detection by channel state information (CSI) in MIMO propagation channel, has been proposed. We have focused on wide range human detection in indoor scenario by applying array antenna with wide element spacing in the horizontal place at transmit and receive antennas. On the other hand, human detection with limited range such as a gate might be needed when considering MIMO sensor application. In this paper, basic performance on the human detection by the MIMO sensor with antennas arranged at ceil and floor is evaluated. The time correlation function is used as the measure on the MIMO sensor. In this paper, the human detection performance when considering multiple users and their waking is evaluated, although only one person is considered in the previous studies.

**Index Terms** — MIMO sensor, propagation channel, time correlation

## 1. Introduction

Reliable security systems have been recently attracted much attention. Microwave sensors using existing signals, such as Frequency Modulation (FM), Television (TV) broad-casts signals and so on, have been studied [1]. This method is relatively simple but there is an issue for the detection accuracy [2]. In order to solve this problem, an intruder detection using array signal processing was proposed [2].

We proposed an intruder detection method which utilizes channel matrix in Multiple Input Multiple Output (MIMO) channel [3], in order to enhance detection performance in [2]. We call this method MIMO Sensor [4]. We have focused on wide range human detection in indoor scenario by applying array antenna with wide element spacing in the horizontal place at transmit and receive antennas [4]. On the other hand, human detection with limited range such as a gate might be needed when considering MIMO sensor application.

In this paper, sensors are located at ceil and floor and the human detection is evaluated when sensors which are installed at a gate is assumed. First, the basic performance on this type of MIMO sensor is evaluated how to detect a person by using the time correlation function. Second, when considering multiple users and their waking, variation on the time correlation is evaluated.

## 2. Measurement setup and environment

Fig. 1 shows the measurement environment. The measurement carried out in a room (8.9x15.8x2.6m, 140m<sup>2</sup>)

in Fig.1. We performed two kinds of following measurements for human detection by using the time correlation in MIMO channel [4]. The number of transmit and receive antennas are eight, respectively: 8x8 MIMO channel is obtained. Sleeve and patch antennas are used as transmit and receive antennas, respectively, and the antenna heights are 0 and 2.2 m: sensors are assumed at floor and ceiling. Center frequency and bandwidth on this measurement is 2.6 GHz and 6 KHz. In order to realize an accurate CSI estimation, the timing and carrier synchronization for CSI estimation using minimum shift keying in [5] is adopted. The details of measurements are shown as follows:

### Measurement 1: Detection performance by one person

One person walked in Course 1, 2 and 3 in Fig. 1 and evaluated detection performance in front and behind of sensors #1 to #8. Each circled number show location of transmit and receive antennas. The distance from a start point to sensors #1 to #4 is 5m and the person walked at about ten second with this range. The time correlation of MIMO channel between  $t=0$  s and  $t$  is obtained ( $t$  is time).

### Measurement 2: Detection performance on simultaneous and separate walks by multiple persons

Four persons walked towards a direction of sensors #1 to #8 in Fig. 2. First, four persons simultaneously moved. Second, the measurement is carried out where four persons individually moved: one person moved to next desk while the other three persons were sitting down and next person moved to next desk after this process. The time correlation was obtained with the same way in the measurement 1.

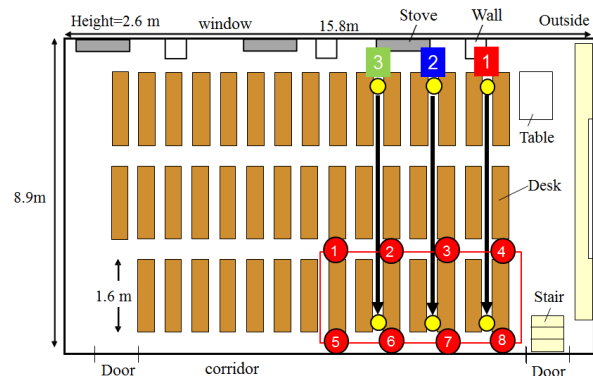


Fig. 1. Measurement environment 1

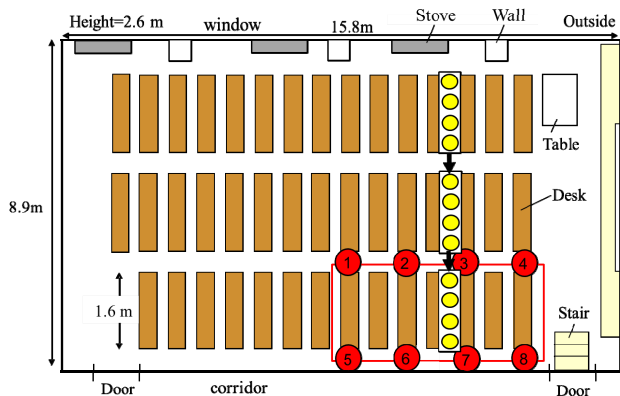


Fig. 2. Measurement environment 2

### 3. Detection performance by MIMO sensor with antennas at ceiling and floor

Fig. 3 shows time correlation versus measurement time when using 2x2 MIMO with the sensors #1 and #4. Regardless of Courses 1 to 3, it is observed that the time correlation is decreased approximately around seven seconds. This result indicates that one person comes to the sensors at seven seconds. On the other hand, the time correlation does not almost change unlike conventional MIMO sensor whose antennas are located at the corner of the room with horizontally wide element spacing. In other words, it was revealed that walk of one person could be detected in limited range when transmit and receive antennas are located at floor and ceiling.

Figs. 4 and 5 show time correlation when four persons walk together and separately. Note that the range of horizontal axis in Fig. 4 is different from that in Fig. 5 because the required measurement time in Fig. 4 is different from that in Fig. 5. 8x8 MIMO is considered in these results. As can be seen in Fig. 4 and 5, the time correlation is greatly decreased when one person and four persons approach sensors (Fig. 4: approximately 10 seconds, Fig.5: approximately 25 seconds). When we focus on the difference on time correlation between Figs. 4 and 5, variation of time correlation in Fig. 4 is larger than that in Fig. 5. As can be seen in Fig. 5, multiple periods are observed and time of variation is longer than that in Fig. 4 because four persons walked in turn. Hence, we found that there is a possibility to

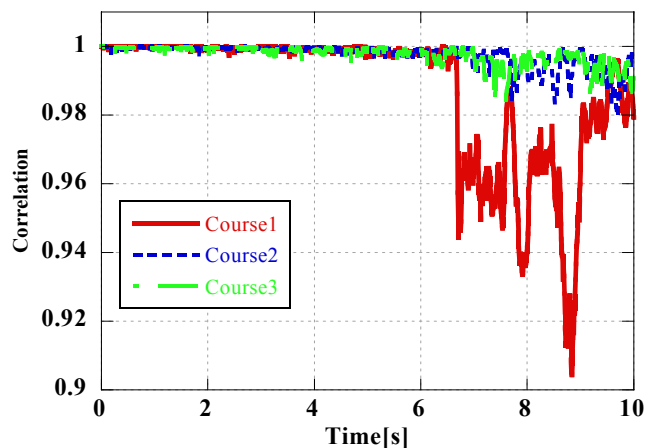


Fig. 3 Time correlation versus time (Measurement 1).

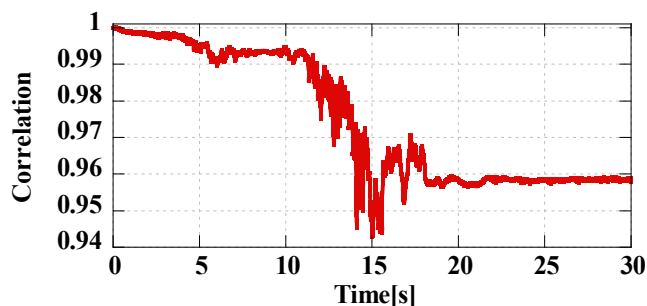


Fig. 4 Time correlation versus time (Measurement 2 with instantaneous walking).

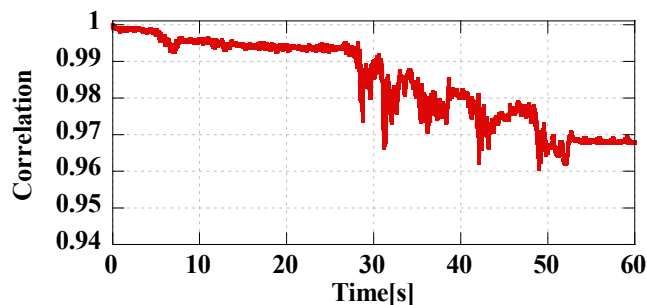


Fig. 5 Time correlation versus time (Measurement 2 with individual walking).

discriminate simultaneous walking and individual walking with multiple users by observing period and range of variation in time correlation.

### 4. Conclusion

In this paper, when considering a single and multiple persons, basic performance on the human detection by the MIMO sensor with antennas arranged at ceil and floor is evaluated. When using this antenna configuration, it is shown that walk of one person could be detected in limited range when transmit and receive antennas are located at floor and ceiling. Moreover, we found that there is a possibility to discriminate simultaneous walking and individual walking with multiple users by observing period and range of variation in time correlation.

### References

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