MEASUREMENTS ON AREA COVERAGE OF 5GHZ BAND MIMO-OFDM SYSTEM IN HOME ENVIRONMENT

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1 Introduction

Multi-Input Multi-Output (MIMO) system is considered as a promising technology to realize high data rate wireless communication systems as summarized in [1]. Numerous measurement campaigns have been conducted to assess the MIMO systems in real propagation environments as in [2, 3, 4]. However, the measurements in these campaigns are found to be either restricted to a small limited area or have insufficient sample points. As a result, there are few reports on the measured area coverage of MIMO systems in the real propagation environments. The area coverage is defined as an area where the target data rate is supported. To measure this area coverage a sophisticated measurement instrument is needed to scan the area continuously and widely.

In this paper, an area coverage of 4×4 MIMO-OFDM system was measured in residential home environment at 5GHz band. A novel spatial scanner was fabricated to suit the needs of measurements in environments with household furniture such as beds, sofa, and tables. The area coverage was calculated based on a total of 55,000 spatial samples in an area of 150m^2 where two rooms, a hallway and living and dining areas are included. The results show that the 4×4 MIMO system can greatly increase the area coverage compared to Single-Input Single-Output (SISO) system especially at high target data rates. It was also found that the introduction of optimum power allocation in the MIMO system is effective to expand the area boundary where the lower data rates are supported.

2 Experimental Setup

Measurement Hardware

Measurement system was constructed by implementing MIMO-OFDM propagation measurement firmware on the MIMO software defined transceiver developed in [5]. The block diagram of the measurement system and measurement parameters are shown in Fig. 1 and Table 1 respectively.

At the transmitter side, the training signals are modified from the IEEE802.11a preamble to be orthogonal between the channels. These signals are generated from the memory tables implemented on the FPGAs in the D/A board. These baseband signals are up-converted to 5.06GHz and transmitted from the 4-element ULA. At the receiver side, the RF signals received by the 4-element ULA are down-converted to the baseband signals and recorded at the memories implemented on the FPGAs in the A/D board. The off-line channel estimation is performed on these received signals to obtain a MIMO channel matrix $\widehat{\boldsymbol{H}}(k)$ where k is a subcarrier index.

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Table 1: Measurement parameters.

MIMO configuration	4(Tx)×4(Rx)
Array configuration	Half a wavelength spacing ULA†
Antenna element	Vertical sleeve dipole
Center frequency	5.06 GHz
Bandwidth	20 MHz
Total transmit power	0 dBm
Noise figure	7 dB typical
Transmit signal	Modified IEEE802.11a preamble
Training signal length	64 OFDM symbols
# of measurement points	55738
Measurement time	500 ms per point

Furthermore, the receive antenna and receiver itself are located on the spatial scanner as shown in Fig. 2 to obtain the spatial samples of MIMO channel matrix $\widehat{\boldsymbol{H}}(k,\Psi)$ by changing the measurement position Ψ. The channel capacity averaged over the subcarriers is calculated from measured $\widehat{\boldsymbol{H}}(k,\Psi)$ in each position by using equations in [6] and is used to analyze the area coverage.

Measurement Environment

The measurement was conducted in the residential home environment with the area of 15m by 10m including two rooms, a hallway and living and dining areas. Location of transmit antenna and measurement areas for scanning the receive antenna are shown in Fig. 3. There are furniture such as beds, sofa, and tables in the room. Measurement areas in the living room are mostly LOS environment and near to the transmit antenna. While the measurement areas in the hallway, bedroom and Japanese room are NLOS environment with walls, doors, and furniture between the transmit and receive antennas. There was nobody present in the home during the measurement to ensure a static environment.

Both the transmit and receive antennas are located on a height of 1m and these endfires are in-line with the x direction in Fig. 3. The whole measurement area is divided into 58 small areas with 60cm×60cm size where the measurement can be carried out without moving the positioner's rail in Fig. 2. In these small areas 961 channel measurements are performed with a step of 2cm in each direction, and it results in total of 55,738 measurement points. The measurement time including channel estimation and spatial scanning is less than 500ms per point, so that the measurement in a wide area with large amount of data samples is possible. It should be noted that the positioner's arm in Fig. 2 makes it possible to measure a realistic environment with household furniture.

3 Measurement Results

By using the whole measured data, the area coverage for the SISO system, 4×4 MIMO system, and 4×4 MIMO system with optimal power allocation are calculated and shown in Fig. 4, Fig. 5 and Fig. 6 respectively. For a simple comparison, the following two steps are introduced. Firstly, the calculated channel capacity is averaged in the 20cm×20cm area where the WSS assumption is assumed to be satisfied. Secondly the average channel capacity is discritized to $\{0,2,4,6,8,16,32\}$bit/s/Hz by flooring the continuous average channel capacity. These discritized channel capacity are referred to as target data rate henceforth. In the figures the maximum distances of the area coverage for different target data rates are shown by the arcs with different colors. By comparing Fig. 4 and Fig. 5, it is found that the 4×4 MIMO system can greatly increase the area coverage compared to the SISO system. This trend is especially remarkable at high target data rates as can be seen in the living room. It is clearly owing to the benefit of spatial multiplexing. From Fig. 5 and Fig. 6, it is also found that the introduction of optimum power allocation in the MIMO system is effective to expand the area boundary as seen in the bedroom and Japanese room where only the lower data rates are supported. It indicates that the MIMO beamforming is useful at the edge of the coverage area.

4 Concluding Remarks

In this paper the area coverage of 4×4 MIMO-OFDM system was measured in the residential home environment where two rooms, a hallway and living and dining areas are included. From the results, it was found that the 4×4 MIMO system can greatly increase the area coverage compared to SISO system especially at high target data rates. On the other hand, the introduction of optimum power allocation in the MIMO system is effective to expand the area boundary where only the lower data rates are supported.

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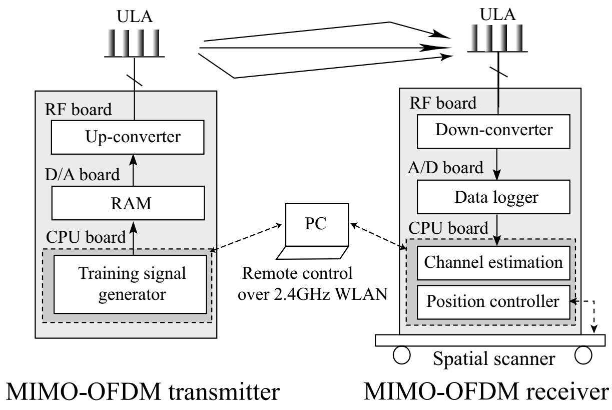

Figure 1: Block diagram of measurement system.

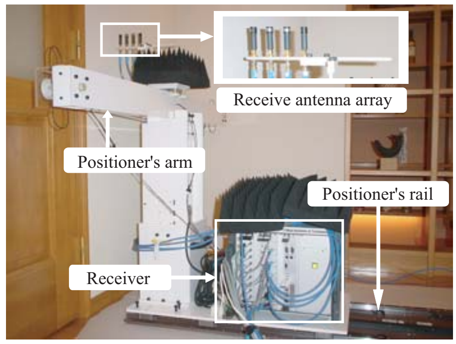

Figure 2: Photograph of receiver setup.

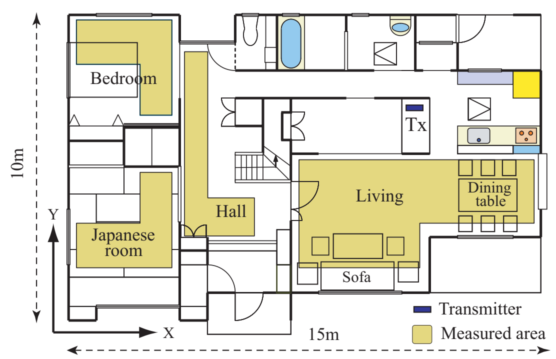

Figure 3: Overview of measurement environment.

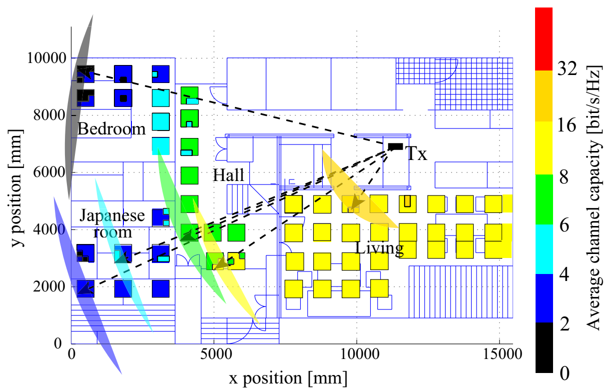

Figure 4: Measured area coverage for SISO.

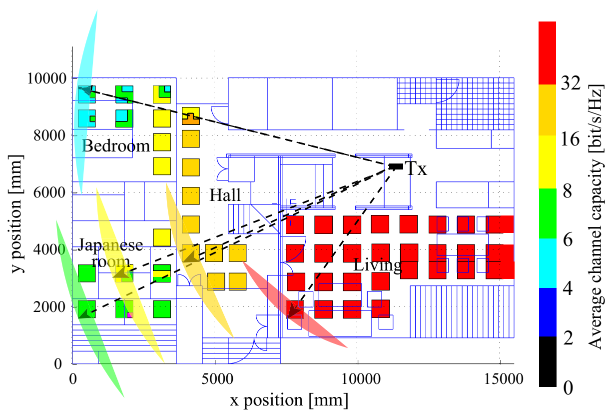

Figure 5: Measured area coverage for MIMO.

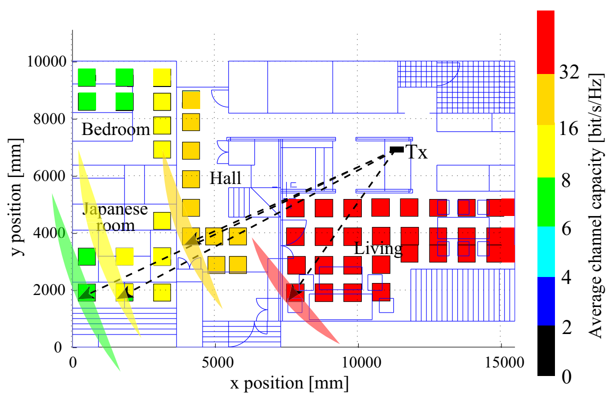

Figure 6: Measured area coverage for MIMO with optimal power allocation.