The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07)

EXPERIMENTAL EVALUATION OF MIMO ANTENA SELECTION SYSTEM USING RF-MEMS SWITCHES ON A MOBILE TERMINAL

Atsushi Honda, Ichirou Ida, Yasuyuki Oishi,
Fujitsu Limited
Kanagawa, Japan

Quoc Tuan Tran
Osaka University
Osaka, Japan

Shinsuke Hara
Osaka City University
Osaka, Japan

Jun-ichi Takada
Tokyo Institute of Technology
Tokyo, Japan

ABSTRACT

This paper describes experimental results of an antenna selection system that is applied to a receiver side of multiple-input multiple-output (MIMO) systems. We proposed an antenna selection system that each MIMO receive branch has different polarization and directional pattern antennas and selects one antenna combination by using radio frequency micro electro mechanical system (RF-MEMS) switches. A 2×2 MIMO-OFDM transmission system is constructed to evaluate the performance of the proposed antenna selection system, which can not only measure real-time bit error rate (BER) but also control the antenna switch based on an antenna selection algorithm. BER measurement experiments were conducted in an indoor office environment, and it was found that more than 3 dB receive power improvement was achieved with the proposed antenna selection system comparing to the vertical polarization fixed receive antennas from the result of the averaged BER performances.

I. INTRODUCTION

Multiple-Input multiple-output (MIMO) systems use multiple transmit and receive antennas, and they are promising technologies for high speed communication systems. In some wireless communication standard task groups such as IEEE 802.11n or IEEE802.16e (WiMAX), the MIMO communication systems are examined to realise high throughput transmission [1, 2]. However, one of drawbacks of the MIMO systems is degradation of the throughput in low signal-to-noise ratio (SNR) environments, also in the case of space division multiplex (SDM) transmissions [3]. To improve the degradation, it is considered effective to apply an antenna selection system to the MIMO systems that select an antenna combination from multiple antennas equipped on a receiver side [4]. We have also proposed an antenna selection system that each MIMO receive branch has different polarization and directional pattern antennas and selects one antenna by using RF-MEMS (radio frequency micro electro mechanical system) switches [5, 6]. The RF-MEMS are mechanical variable devices, which have good characteristics of insertion loss and linearity [7].

In the previous works, we have proposed antenna selection algorithms, and they were evaluated through computer simulations using measured propagation channel in an indoor environment [8]. The numerical results showed good performances of bit error rate (BER), and thus we planed to evaluate the proposed algorithm in real-time data transmission. In this paper we construct a 2×2 MIMO transmission system and conduct BER measurement experiments in an indoor office environment.

The rest of the paper is as follows. Section Ⅱ describes the configuration of the proposed receive antennas for MIMO communication systems. Section Ⅲ describes the constructed MIMO transmission system to evaluate the proposed antennas. Section Ⅳ describes the experimental results, BER performance measured in an indoor office environment. Finally, concluding remarks are provided in Section Ⅴ.

II. ANTENNA SELECTION USING RF-MEMS SWITCHES

Figures 1 and 2 show the proposed antenna configuration, and the picture. Each MIMO receive branch has three types of antennas that have different polarization and directional patterns such as vertical polarization (V), horizontal polarization 1 (H1), and horizontal polarization 2 (H2). Each antenna has each feeding point, which is selected by using RF-MEMS switches. The RF-MEMS switches used in this configuration are SPDT type switches [9], and thus the switching circuits for three feed point antennas are realised by using two switches with cascade arrangement. Because each MIMO branch selects one antenna from the three antennas, there are 3 × 3 = 9 combinations of antennas. From these antenna combinations, one combination is selected which is suitable to the propagation environments, and thus the communication quality can be improved.

III. EXPERIMENTAL SETUP

We constructed a transmission system that is assumed as 2×2 MIMO-SDM. Table 1 shows the antenna configuration for the experiments. Tx and Rx mean transmitter and receiver. The antenna spacing of the Tx and Rx antennas (equivalent to the branch spacing) are set to 5λ and 1.5λ, considering sufficient low correlation and size for practical use.

Figure 3 shows the block diagram of the transmission system. In the transmitter side, two transmitters output different OFDM signals based on IEEE802.11a [10]. Table 2 shows parameters of the transmitted signal. The transmitted bits are coded by convolutional encoder, and QPSK modulated. In the receiver side, as shown in Fig. 3, two received signals pass through the RF switches, and they are down-converted to IF (140MHz) band signals. The IF signals are combined with additive white Gaussian noise (AWGN) to change the receive SNR for BER curve measurements. After that, the IF signals are digitized by A/D converters and processed at field programmable gate array (FPGA). The digital signal processing is almost the same as that of general wireless LAN (i.e. synchronization, FFT, channel estimation, IQ demodulation, de-interleaving, and vitervi decoding), although it includes zero-forcing method to separate the MIMO signals. The decoded bits are compared with transmitted bits, and thus BER is calculated.

On the other hand, the channel estimation results are also used in the antenna selection algorithm processing part. In the processor, cost function is calculated based on channel matrix and receive signal-to-interference-plus-noise ratio (SINR) for each antenna combination [8]. Here one antenna combination that has the smallest cost function is selected, and the DA converter in the processor applies the output voltages to the RF-MEMS switches to select the desired antenna combination. Therefore, the MIMO transmission system can evaluate the proposed antenna selection system in real-time BER measurements.

Table 1: Antenna configuration for experiments.

Items	Parameters
MIMO branch	Tx : 2, Rx : 2
Tx antennas	Vertical polarization
Rx antennas	Proposed antennas
Antenna spacing	Tx side : 5 λ Rx side : 1.5 λ

Table 2: Parameters of transmitted signals.

Items	Parameters
Frequency	5.06GHz
Baseband signal	Based on IEEE 802.11a
Modulation scheme	QPSK
Coding	Convolutional cording (R = 1/2, K=7)

IV. Experimental Results

A. Environment of experiments

The Experiments were conducted in a room that was considered as a typical office environment. Figure 4 shows the experimental environment. The Tx and Rx in the figure indicate positions of the transmit and receive antennas. The Tx and Rx antennas were placed on a line-of-sight (LOS), and the distance was 3 m. The Rx was moved 3 cm distance (about 1/2 λ) from the initial setting point for each measurement, and the BER was measured in each point.

B. Results of experiments

The measurements were conducted in 8 points. Figures 5 - 7 show the several results of the BER measurements. The vertical axis shows BER and the horizontal axis shows the noise power to change the SNR. The more the noise power is (left-hand side of the graphs), the less SNR is. The graph legends, V-V, V-H1, … means receive antenna combination (ex. V-V indicates vertical and vertical polarization antenna), and the antennas are fixed for each measurement. On the other hand, the Proposal means with antenna selection algorithm that selects one antenna combination from 9 candidates based on channel matrix and receive SINR.

Comparing the Figs. 5 - 7, the BER performances are largely different in each measurement position. In Fig. 5, the BER performance of antenna combinations that include V polarization show good performance, although that includes H2 polarization is deteriorated. On the contrary, in Fig. 6 the antenna combinations include V polarization is not good, that of H1-H2 and H2-H2 shows good BER performances. Thus, the performances of BER are quite different in each point, and the advantageous antenna combination is also different. On the other hand, when the proposed antenna selection method is used, because the antenna combinations suitable for the propagation channel are selected, the BER performances show good in Figs. 5 - 7. Figure 8 shows the averaged BER performance of 8 measured points. It is found that the proposed antenna selection method improves BER characteristics about 3 dB equivalent receive power comparing fixed antenna combinations as V-V and so on.

V. Conclusion

To improve receive SNR of MIMO systems, an antenna selection system using RF-MEMS switches was proposed. The constructed 2×2 MIMO transmission system can control the proposed antennas and measure BER in real-time. The BER measurement experiments was conducted in an indoor office environment, and the performances were compared in the case with receive antenna selection and fixed receive antennas such as vertical and vertical polarization (V-V) and so on. In the indoor multi-path propagation environment, the receive SNR is fluctuated even in the receiver moving slightly, and thus advantageous antenna combinations are quite different in each point. The proposed antenna selection system can select the antenna combination that is good BER performance in each measured position. As the results, it was found that more than 3 dB improvement of receive SNR was achieved from the averaged BER performance of 8 measured points.

Acknowledgment

This research was supported by National Institute of Information and Communications Technology of Japan.

References

[1] "IEEE 802.11n Task Group," http://grouper.ieee.org/groups/802/11/Reports/tgn_update.htm

[2] "IEEE 802.16e Task Group," http://grouper.ieee.org/groups/802/16/tge/index.html

[3] G. J. Foschini and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," *Wireless Pers. Commun.*, vol.36, pp.744-756, Mar. 1998.

[4] F. Molisch, and M. Z. Win, "MIMO systems with antenna selection," *IEEE Microwave Magazine*, pp. 46-56, Mar. 2004.

[5] Y. Nakaya, A. Honda, I. Ida, S. Hara, and Y. Oishi, "Measured Capacity Evaluation of Indoor Office MIMO System using Receive Antenna Selection," *IEEE VTC Spring*, May 2006.

[6] A. Honda, Y. Nakaya, K. Yokoo, I. Ida, S. Hara, J. Takada, Y. Oishi, "Performance Evaluation of an Antenna Selection MIMO system with RF Switches in Mobile Terminals," *IEEE VTC Fall*, Sep. 2006.

[7] G. M. Rebeiz, "RF MEMS Technology, Design, and Technology," Wiley-Interscience, 2003.

[8] Q. T. Tran, S. Hara, A. Honda, Y. Nakaya, I. Ida, and Y. Oishi, "A Receiver Side Antenna Selection Method for MIMO-OFDM System," *IEEE VTC Fall*, Sep. 2006

[9] T. Nakatani, A. T. Nguyen, T. Shimanouchi, M. Imai, S. Ueda, I. Sawaki and Y. Satoh, "Single Crystal Silicon Cantilever-Based RF-MEMS Switches Using Surface Processing on SOI," *Proc. 18th IEEE Int. Conf. on MEMS*, pp. 187-190, Feb. 2005.

[10] IEEE Std. 802.11a, "Wireless medium access control (MAC) and physical layer (PHY) specifications: high-speed physical layer extension in the 5 GHz band," IEEE, 1999.

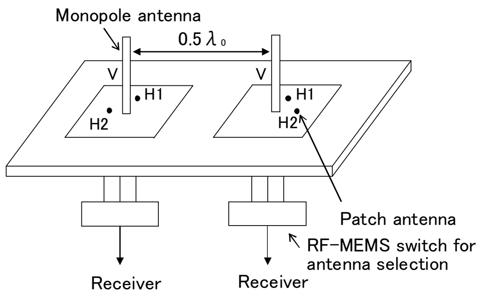

Figure 1: Proposed receive antenna configuration

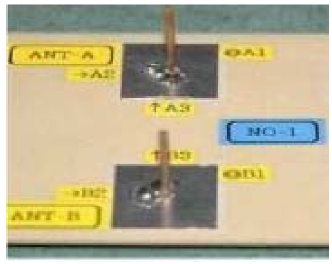

Figure 2: Photograph of the antennas

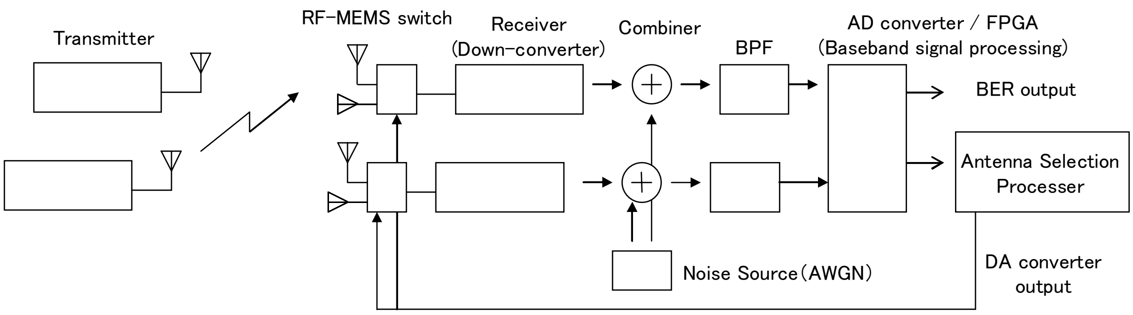

Figure 3: Experimental setup with 2×2 MIMO transmission system.

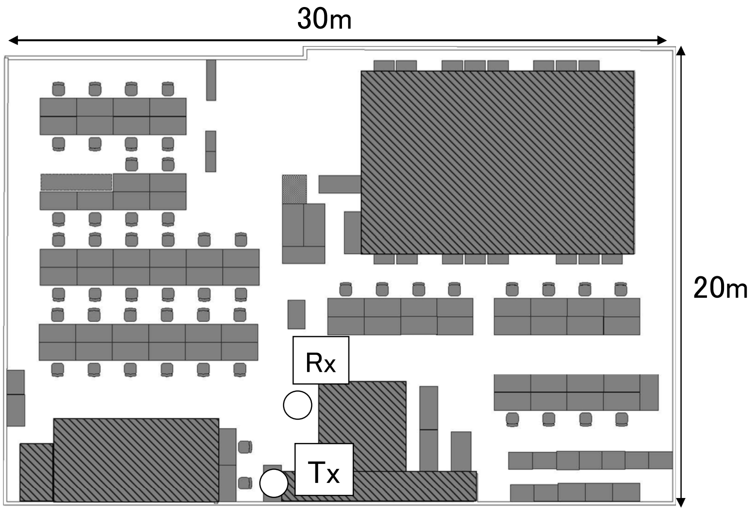

Figure 4: Experimental environment, the Tx and Rx indicate the positions of transmit and receive antennas.

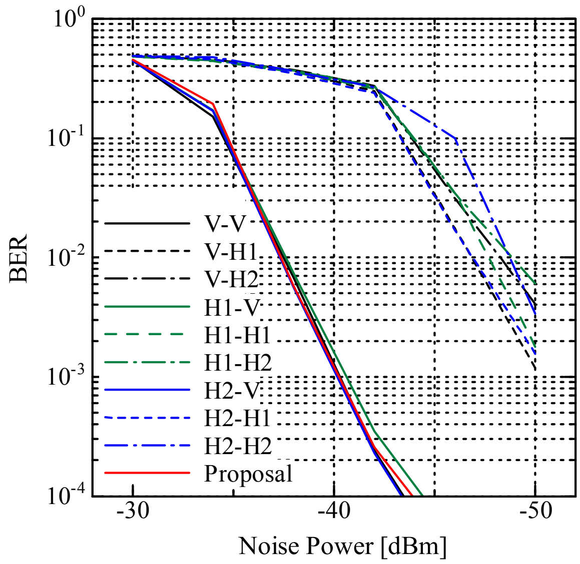

Figure 5: BER performance (point1).

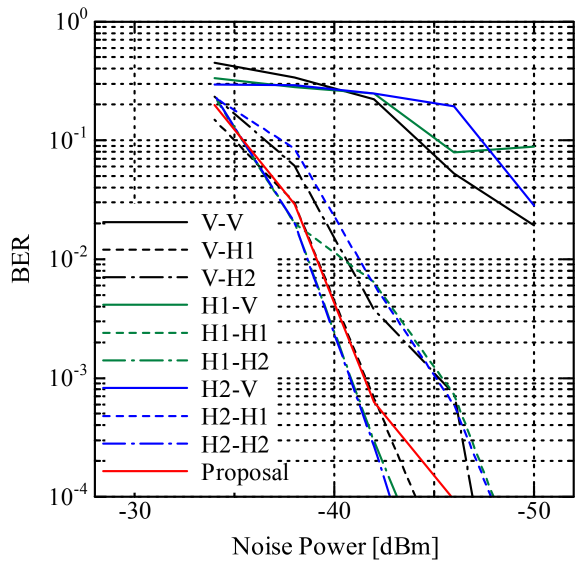

Figure 7: BER performance (point3).

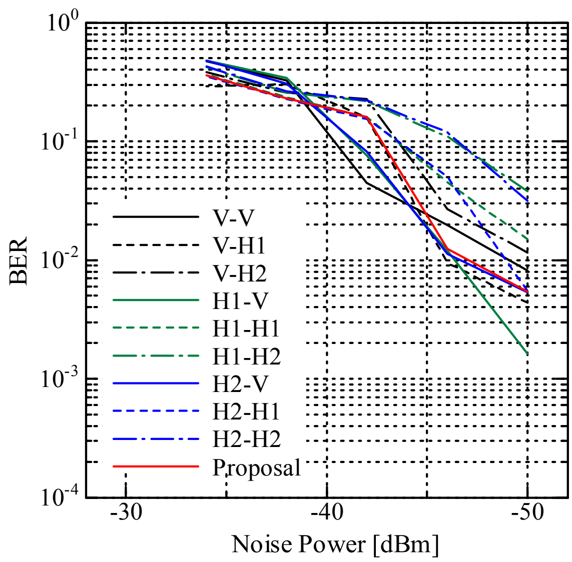

Figure 6: BER performance (point2).

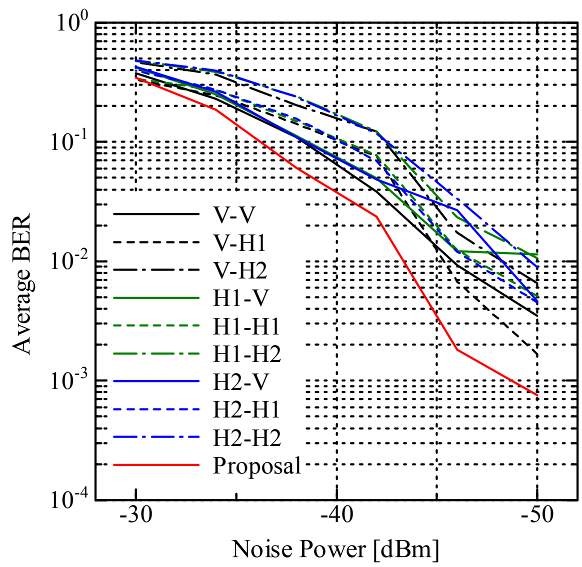

Figure 8: Averaged BER performance (point 1 to 8).