Channel Capacity of Multi-User Full-Duplex MIMO in Actual Outdoor Environment

Yuta Kashino[1], Naoki Honma[1], Masakuni Tsunezawa[1], and Kentaro Nishimori[2]
[1]Graduate School of Engineering, Iwate University, 4-3-5 Ueda, Morioka, 020-8551, Japan
[2] Graduate School of Science and Technology, Niigata University, 42-8050, Ikarashi, Niigata, 950-2181, Japan

***Abstract* - In this paper, we propose the new scheme, multi-user full-duplex MIMO (Multiple-Input and Multiple-Output) system, which performs uplink and downlink signal transmissions at the same frequency and time between the base station and multiple terminals. We show the characteristics of the transmission capacity of the proposed full duplex MIMO system by use of the channel information measured in an actual outdoor environment.**

***Index Terms* — full duplex, MIMO, transmission capacity.**

1. Introduction

In recent years, there is an increasing demand for higher communication speed because of the growth of rich content and the diversification of mobile communication systems. Hence, we are facing a problem in shortage of frequency resources, which is a key challenge in the latest studies on the wireless communication. Especially, the full-duplex system has been studied as one of the important technologies to save frequency resources, which performs uplink and downlink signal transmissions at the same frequency and time, where the transmitting antenna (Tx) is highly isolated to the receiving antenna (Rx)[1].

This system theoretically doubles the transmission speed compared to TDD (Time Division Duplex) method, which has been commercially used in many wireless systems, but the most of the studies on the full-duplex have dealt with SISO (Single-Input and Single-Output) systems. The extension of full-duplex technique to MIMO has been presented [2], [3], but these technique cannot be applied to the mobile terminal because of the size limitation for the antennas. Therefore, we still need to find the feasible solution in the self-interference reduction in the mobile terminal.

In this paper, we propose a new full-duplex scheme, where uplink and downlink users share the same frequency channel. In our idea, the transmission and reception are performed at the different user terminals (UTs), while the base station (BS) performs simultaneous transmission and reception. This scheme is defined as "multi-user full-duplex MIMO (Multiple-Input and Multiple-Output)" in this study. We conducted the MIMO channel measurement in an actual environment to show the capacity of the proposed full duplex MIMO system.

2. The Proposed System Model

Fig. 1 shows a system model of the proposed full duplex system dealt with in this study. This system model assumes the following situation: the uplink user terminal 1 (UT1) and downlink user terminal 2 (UT2) communicate to the BS at the same time. Placing transmitting antenna and receiving antenna separately in the BS enables a simultaneous communication through the uplink channel ($\boldsymbol{H}_1$) and downlink channel ($\boldsymbol{H}_2$). But the interference occurs between these two UTs because the signal transmitted from the UT1 reaches the UT2 via the interference channel ($\boldsymbol{H}_{21}$). Though the separated transmitting and receiving antenna in the UTs alleviate the intense self-interference inside the UTs, the one of the UTs is interfered by the other UT.

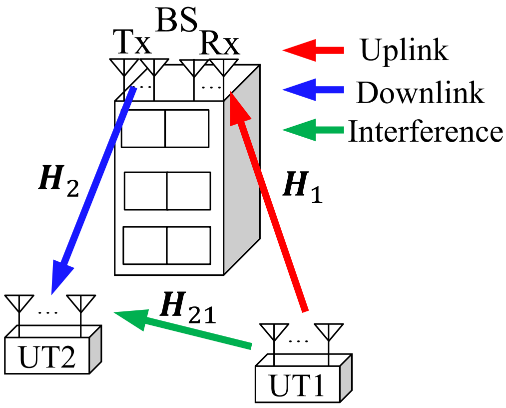

Fig.1 Multi-user full duplex system model

To solve this problem in this study, an eigen-beamforming technique is introduced for alleviating the interference through H_{21}, i.e. UT1 direct the null directivities to UT2. Also, the capacity improvement effect is evaluated when the interference between UTs is suppressed by use of the measured propagation channel in an actual outdoor environment.

3. Measurement Conditions and Experimental Results

In this measurement campaign, the center frequency was set to 2.47125 GHz. This experiment assumed that the two terminals simultaneously communicate with the base station. The base station antenna comprises eight subarrays, each of which has vertical four-element patch antennas fed by a parallel feed network. In the full-duplex scheme, four subarrays are used for transmission and remaining four subarrays are used for reception. Each terminal has a four-element sleeve linear array, where the inter-element spacing was set to 0.5λ (λ: wavelength in a vacuum).

Fig. 2 shows a measurement environment and route. In this photo, three points, i.e. A, B, and C, are shown and they are on a line. The point A is 65 m away from the point C, and the point B exists at the middle of them. The UT2 was always located at the point C, which is just under the building of the BS. The all channels among the BS, the UT1, and the UT2 ($\boldsymbol{H}_1$, $\boldsymbol{H}_2$, and $\boldsymbol{H}_{21}$) were measured when the UT1 is moved from the point A to the point C by way of the point B.

Fig. 3 shows eigenvalue characteristics of two different channels versus the location of UT1, which is explained by d (the distance from the point C). The result (i) shows eigenvalues of the channel between the BS and UT1, and (ii) shows eigenvalues of the channel between the UT1 and UT2. In this result, the rank of the interference channel between UT1 and UT2 was not degenerated compared with the uplink channel between BS and UT1.

Fig. 4 shows the CDF (Cumulative Distribution Function) of various channel capacities calculated from the measured channels. FD w/ and w/o BF represent the full-duplex capacities with and without the proposed beamforming scheme. TDD represents the capacity when TDD scheme is used. In FD and TDD schemes, we assumed that one uplink and one downlink users exist, and the average capacities of two users are calculated. MU-MIMO represents the broadcast channel capacity with a multi-user MIMO scheme, where four subarrays are used at the BS. From this result, the full duplex system with beamforming realizes high channel capacity compared to the full duplex system without beamforming, and improves the median value of the transmission capacity by 10.5 and 6.84 Bits/s/Hz compared to that of the TDD and MU-MIMO, respectively, when the UT1 exists between A and B. Similarly, the full duplex system with beamforming improves the median value of the transmission capacity by 2.41 and 1.61 Bits/s/Hz compared to TDD and MU-MIMO, respectively, when the UT1 exists between B and C.

4. Conclusion

In this paper, we have proposed a multi-user full duplex scheme, and the channel capacity of the proposed scheme by use of channel information measured in an actual outdoor environment has been presented. The proposed scheme achieves higher channel capacity than the conventional scheme does irrespective of distance, and improves the median capacity by 2.41 and 1.61 Bits/s/Hz compared to TDD and MU-MIMO when the UTs perform beamforming to suppress the inter-user interference.

References

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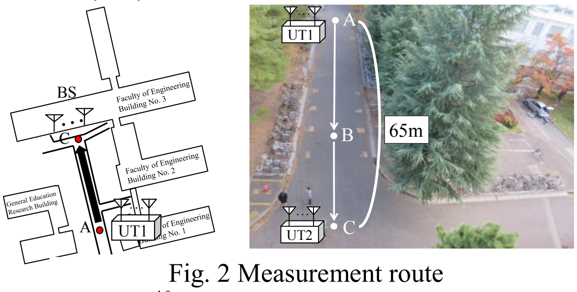
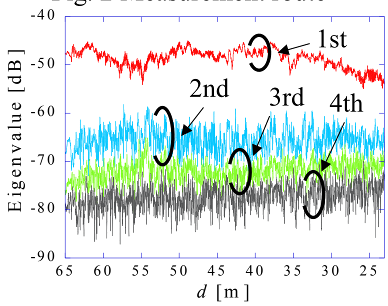
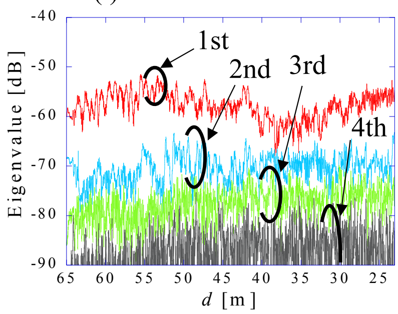


Fig. 2 Measurement route

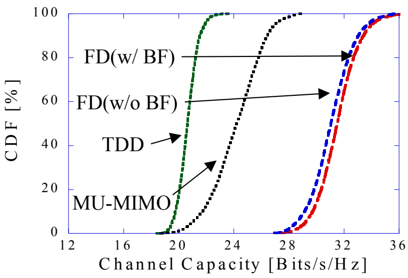


(i) Between BS and UT1

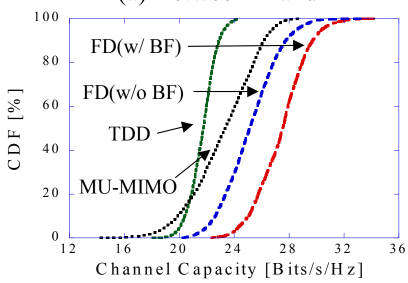


(ii) Between UT1 and UT2

Fig. 3 Characteristics of eigenvalues



(a) Between A and B



(b) Between B and C

Fig. 4. Characteristics of transmission capacity