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Enabling Full-Duplex MIMO Communication Exploiting Array Antenna Arrangement

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***Abstract* – This paper presents the developed in-band full-duplex testbed and its performance. The testbed uses two linear array antennas in an end-fire arrangement, which is convenient to suppress the self-interference by transmitting beamforming. The experimental results demonstrate the proposed testbed realizes the interference suppression by about 90 dB even with the normal and feasible transceiver configuration.**

***Index Terms* — Full-duplex, end-fire arrangement, MIMO, OFDM.**

1. Introduction

An in-band full-duplex communication (IBFD) is a one of the challenges toward next generation wireless network because this scheme ideally doubles the spectral utilization efficiency by sharing the same frequency channel between the uplink and downlink transmissions. Although the IBFD provides the significant benefit, such as the data-rate enhancement, this has a serious problem, that is, a self-interference [1]

The self-interference in IBFD is defined as the signal leakage from the transmitting antennas to the receiving antennas, which is significantly intense compared to the desired receiving signals. For example, assume that the base station has both transmitting and receiving array antennas, and now the desired uplink signal from the mobile terminal arrives at the base station antennas, while the base station antennas transmit the downlink signal to the other mobile terminal. The desired uplink signal strength is about -90 dBm, and the transmitted downlink signal strength at the base station antenna is +10 dBm. The intensity difference between the receiving and transmitting signal is about 100 dB (note that this value varies depending on the distance, frequency, etc.). Therefore, the IBFD tranceiver needs to have an extraordinary ability to suppress the self-interference.

Many works about the self-interference suppression for IBFD have been investigated, most feasible method is a multi-stage cancellation technique [1]. The first stage is RF stage, where the coupled signal between the transmitting and receiving antennas is cancelled. The second stage is baseband processing. Since the self-interference is a known signal, the interference is simply subtracted at the baseband stage. The problem at the baseband stage is a dynamic range of the analog-to-digital converter (ADC), which is normally about 50~60 dB. Hence, the RF-stage interference cancellation is significantly important even though the content and waveform of the interference are known. However, the RF-stage cancellation becomes significantly

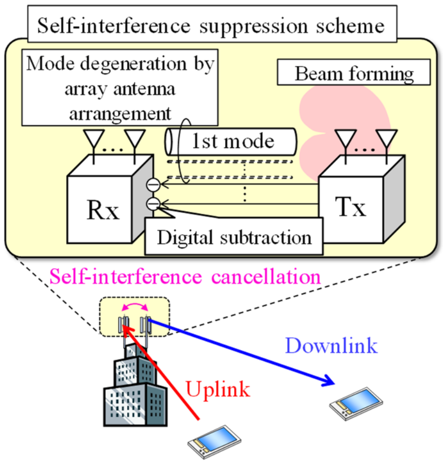

Fig. 1. Conceptual overview of IBFD

difficult if multiple-input multiple-output scheme is used because the multiple interference signals arrive at the receiving antennas through multiple paths. This means RF-circuit for self-interference cancellation shall be 'mesh' network because all antenna ports between transmitter and receiver sides needs to be connected.

The authors have studied the self-interference cancellation technique exploiting the antenna arrangement and beamforming technique, which allows no connection between transmitter and receiver sides at RF-stage [2]. A key idea of these arrangements bases the degeneration of the self-interference path, i.e. only a single mode dominates in the channel between two arrays. For example, two linear arrays are lined in an end-fire direction each other, and therefore all the array antenna elements are observed in a same direction. In this case, the number of the effective eigenmodes is reduced to one if there is no multipath and the distance between two arrays are sufficiently long.

This paper newly presents the experimental evaluation results of IBFD transceiver using the arrays with the end-fire arrangement. We developed an IBFD multiple-input multiple-output (MIMO) testbed, which can transmit and receive the OFDM signals at 12.9 GHz band. The actual self-interference suppression performance is experimentally demonstrated by using the realistic OFDM signal.

2. IBFD scheme

Fig. 1 shows the overview of the IBFD scheme dealt with in this paper. The base station has two array antennas, i.e. one is for transmitting and the other is for receiving. The base station simultaneously transmits and receives the signals by using same frequency channel. Therefore, the strong interference arrives at the receiving array if no countermeasures are taken. In this paper, the channel between the transmitter and receiver at the base station is defined as a self-interference channel. Two array antennas are arranged to degenerate the mode in the self-interference channel. At the transmitter side, the eigen-beamforming technique is used to direct the null to the 1st (the largest) mode. By this procedure, most of the interference power is suppressed, and only a limited power arrives at the receiver. Nevertheless, the remaining modes with quite low gain still yield the interference. This remaining interference can be subtracted digitally because the contents and waveform of the interference signal are known. By this scheme, the uplink and downlink are simultaneously maintained at the base station. The inter-terminal interference is also caused, but this interference can be also suppressed by the linear beamforming technique or nonlinear technique [3].

3. IBFD Testbed

Fig. 2 shows the photo of the developed IBFD testbed. This testbed consists of the transmitting and receiving array antenna (8 × 8 MIMO). The transmitter and receiver have the up converter and down converter, respectively, where they are incorporated with the amplifiers. The baseband processor is also developed, and this enables simultaneous modulation and demodulation. At the receiving array antenna, the RF feed network is configured to alleviate the self-interference, where the mechanism and configuration of the circuit will be detailed in the presentation. The operation frequency of this testbed is 12.9 GHz with 2 MHz bandwidth.

4. Result

The measurement is carried out in an outdoor open-space environment to prevent from the scattered path from surrounding objects. The 8-element linear arrays are used at both transmitting and receiving sides, and two arrays were in the end-fire arrangement. The number of the subcarriers are set to 1024, where the only central 512 subcarriers are used for suppressing the spurious components. First, the training signal is transmitted to the receiving array, and the interference channel is estimated. Second, the eigenvector at the transmitter side is calculated by using singular value decomposition, which is used for the transmitting beamforming. Third, the transmitting beamforming is applied to the transmitting array, where the dominant mode is eliminated. Fourth, the remaining interference is reproduced by using known transmitted signal and estimated interference channel. Fifth, the reproduced interference is subtracted from the received signal at the receiver baseband stage.

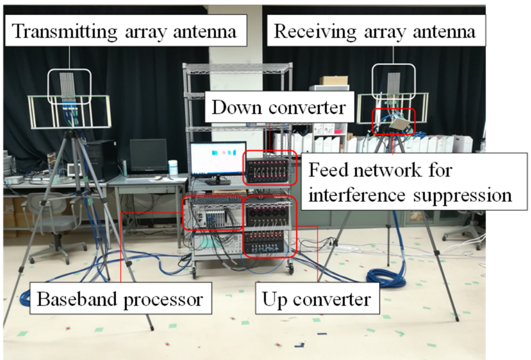

Fig. 2. Developed IBFD testbed

Fig. 2 indicates the spectrum of the transmitted and received signal showing the signal intensity difference between them. It is seen that the power difference was about 90 dB in this measurement. The performance is a little worse than expected one because of the noise from the transmitting amplifiers. This can be improved by increasing the accuracy of the channel estimation, e.g. the number and period of the training process are increased. Nevertheless, a large suppression effect is attained by using simple and feasible transceiver configurations.

5. Conclusion

This paper has presented the developed IBFD testbed and its performance. It was found that the proposed testbed realizes the interference suppression by about 90 dB, which is close to the expected performance.

Acknowledgment

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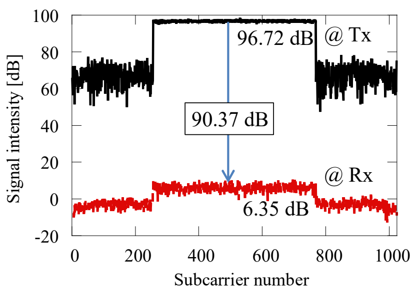

Fig. 3. Signal spectrum