

Self-interference Reduction in Full-duplex Repeater Using Realistic MIMO-OFDM Signal with End-fire Arranged Arrays

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Abstract – In this paper, the self-interference reduction method suitable for the MIMO (Multiple- Input Multiple- Output) full-duplex repeater is presented. The combination of an eigen-beamforming and end-fire arrangement of linear Tx and Rx array significantly reduces the self-interference only at cost of a single degree-of-freedom. Moreover, the remaining self-interference is suppressed by using a digital subtraction technique. The experimental results showed that the proposed method successfully suppresses the self-interference by 76 dB.

Index Terms — MIMO full-duplex, self-interference

1. Introduction

The repeater stations are constructed for the coverage area expansion of the base station. The repeater stations have mainly used the TDD (Time Division Duplex) for the duplex scheme [1]. The TDD scheme prevents the transmission signals from interfering the reception signals by assigning a different time for the transmission and reception. However, the TDD scheme has a problem in the consumption of time resources. The full-duplex system has been proposed to adopt it to the repeater station [2]. The full-duplex system transmits and receives the signals at the same time and frequency. The full-duplex communication can obtain theoretically the double channel capacity compared with that of the TDD. However, the receiver of the full-duplex system receives the self-interference signals of own transmitter. The self-interference suppression technique suitable for the MIMO full-duplex has been proposed, where an eigen-beamforming with the end-fire arranged Tx and Rx arrays is used [3]. The eigen-beamforming technique suppresses the interference by directing the null directivity to the first mode of the interference channel. However, the self-interference signals slightly remain because the mode in the interference channel does not perfectly degenerate in actual repeater due to the antenna manufacturing error and multi-path reflection around it. Therefore, it is necessary to evaluate the interference suppression performance by using the actual signals because this method has been verified only by the S-parameter.

In this paper, we experimentally evaluated the self-interference reduction performance when the eigen-beamforming at the transmitter side and digital subtraction technique at the receiver side are combined. A digital subtraction technique simply eliminates the remaining self

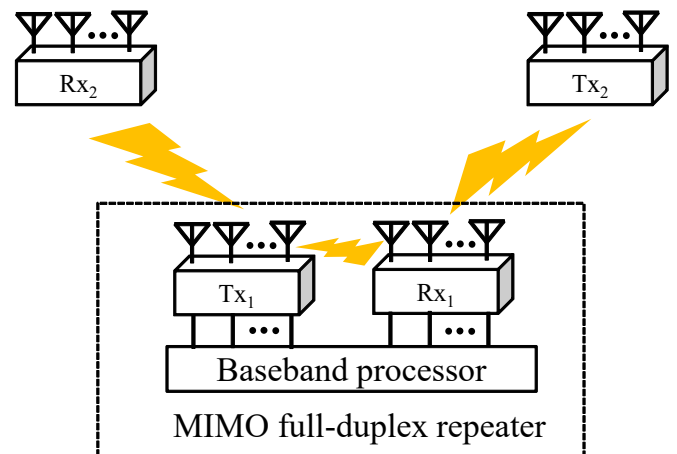


Fig. 1 System model of the MIMO full-duplex repeater

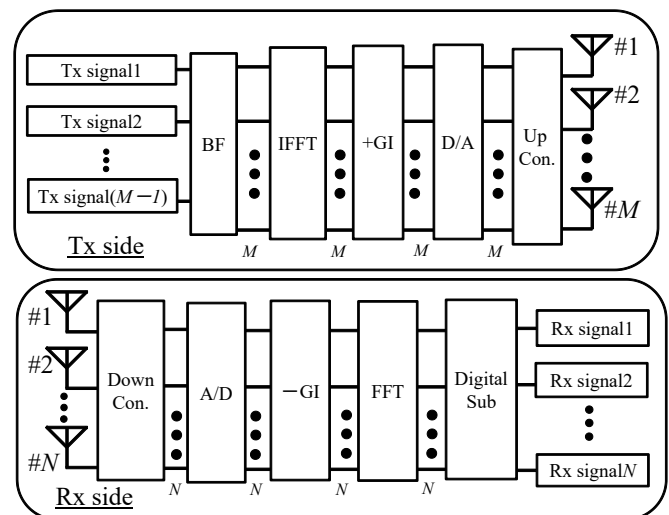


Fig. 2 Block diagram of the baseband system

-interference signals. An experiment was conducted using the MIMO-OFDM (Orthogonal Frequency Division Multiplexing) signals in the anechoic chamber to demonstrate the performance of this technique.

2. Self-interference reduction method

Fig. 1 shows the system model of the MIMO full-duplex repeater. The MIMO full-duplex repeater is consisted of the transmitter Tx₁ and receiver Rx₁. M_i and N_i are the number of antennas at the transmitter (Tx_i) and receiver (Rx_i), respec-

tively. The MIMO full-duplex repeater uses the eigen-beamforming in the end-fire arrangement [4]. The eigen-beamforming technique obtains the eigen-modes from singular value decomposition of the interference channel between the transmitter (Tx₁) and receiver (Rx₁). The transmitter suppresses the eigen-modes of high singular values. However, the degree-of-the-antenna is reduced if the transmitter suppresses many eigen-modes. Therefore, the spatial correlation of the interference channel is intentionally increased by arranging the transmitter and receiver linear arrays in the end-fire direction. The transmitter suppresses the interference by directing the null to the first eigen-mode. However, the interference by this eigen-beamforming technique remains because the eigen-values do not become 0 completely. The digital subtraction is used after the reception of the signal in baseband. In our system, we assume the transmission signals are shared by the transmitter and receiver because they are placed closely and sharing information is not difficult in an actual situation. The receiver estimates the eigen-mode and channel by using the training signal from the transmitter, and the interference signals by way of the Tx and Rx antennas is estimated. The signals after the digital subtraction \mathbf{y}_{SUB} is

$$\mathbf{y}_{\text{SUB}} = \mathbf{y} - \mathbf{H}\tilde{\mathbf{V}}_1\mathbf{s} \quad (1)$$

where \mathbf{y} is the received signal, \mathbf{H} is the channel between the MIMO full-duplex transmitter and receiver, $\tilde{\mathbf{V}}_1$ is the eigmitted signal.

Fig. 2 shows a block diagram of the baseband system. M and N are the number of the antenna at the transmitter and receiver. The eigen-beamforming and digital subtraction technique are carried out in the baseband system. The eigen-beamforming is carried out on the transmission signals before IFFT (Inverse Fast Fourier Transform). The number of transmission signal is $(M - 1)$ because the first eigen-mode is not used. The transmission signals after the eigen-beamforming are converted to the time domain by IFFT, and the up converter converts them to RF (Radio Frequency) signals. At the receiver, the down-converter converts the received signals to the baseband signals, and the signals are FFT-transformed. The digital subtraction technique removes the remaining interference signals from the signal after FFT.

3. Experimental result using MIMO-OFDM signals

Fig. 3 shows the measurement environment. The transmitting and receiving antennas include linear array antennas each of which consists of four half-wavelength sleeve antennas. The center frequency is 2.47GHz. For the linear array antennas, the element spacing $d_{\text{element}} = 0.5\lambda_0$ (λ_0 : wavelength in vacuum), and the center-to-center distance between Tx and Rx $d_{\text{Tx-Rx}}$ is varied from $5\lambda_0$ to $12\lambda_0$. Experiment was carried out in the anechoic chamber in order to avoid the effect of the reflection around the antennas on the interference channel \mathbf{H} .

Fig. 4 shows the interference suppression level versus distance of Tx-Rx. The interference suppression level is defined as the difference between the transmission power and the received power after the digital subtraction. By comparing the interference suppression levels with and without using an eigen-beamforming (w/ BF and w/o BF), it is found that the interference suppression effect larger than 20 dB is realized

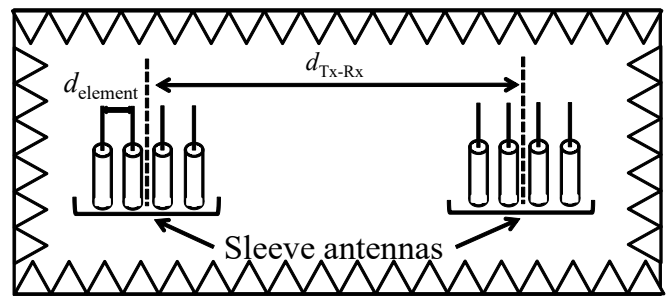


Fig. 3 Measurement environment

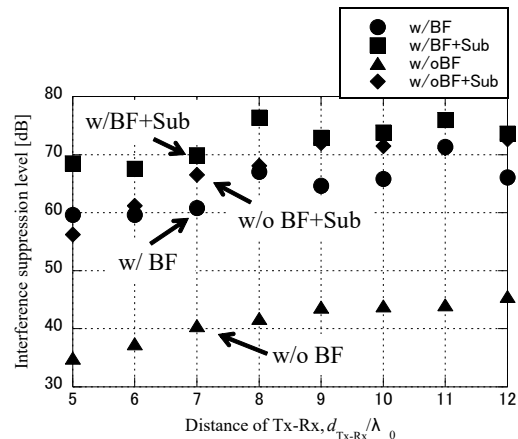


Fig. 4 Interference suppression level versus distance of Tx-Rx in all of the distance between Tx-Rx. The maximum interference suppression level by the combination of the eigen-beamforming and digital subtraction (w/ BF+Sub) is 76 dB at $d_{\text{Tx-Rx}} = 8\lambda_0$. The combination of the beamforming and subtraction techniques suppresses the maximum interference by up to 12 dB higher than the subtraction without the beamforming technique (w/o BF+Sub) does.

4. Conclusion

This paper has experimentally evaluated the self-interference reduction performance of the transmit-beamforming and residual interference subtraction technique suitable for MIMO full-duplex repeater. The measurement results showed this technique offers the interference suppression by up to 76dB. This result demonstrated the presented technique works well even with the realistic MIMO-OFDM signals.

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