Experimental Study on Blind MIMO Transmission by using ICA

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1. Introduction

In the MIMO system, transmitted streams are multiplexed spatially at the same frequency. This causes inter-stream interference at the receiver. Therefore, equalization/decoding method is necessary. Least Squares Channel Estimation (LSCE) [1] is often used as the method. However, overhead of throughput due to training symbols is a problem for effective transmission. In this report, we employ Independent Component Analysis (ICA) [2] as a blind method without the training symbols. We have reported effectiveness of the ICA with a small number of training symbols compared with that of the LSCE [3]. These training symbols is just used for phase correction of each stream, not for channel estimation. However, since the ICA is a statistical channel estimation method, many data symbols are often needed. In this report, we propose to apply a pre-filtering processing scheme to the transmitting signals to obtain better performance compared with the conventional ICA. Computer simulation results are shown to demonstrate availability of the method. Furthermore we provide indoor experimental results to verify the effectiveness of the method in the real environment.

2. Data Model

We consider a MIMO system consisting of N_t transmitting antennas and N_r receiving antennas. The received vector, $\boldsymbol{x}(t) = [x_1(t) \quad x_2(t) \quad \cdots \quad x_{N_r}(t)]^T$, at the receiver can be given by

$$\boldsymbol{x}(t) = \boldsymbol{H}\boldsymbol{s}(t) + \boldsymbol{n}(t), \tag{1}$$

where $\boldsymbol{H}$ denotes the $N_r \times N_t$ MIMO channel matrix, $\boldsymbol{s}(t) = [s_1(t) \quad s_2(t) \quad \cdots \quad s_{N_t}(t)]^T$ is the transmitted symbol vector, and $\boldsymbol{n}(t) = [n_1(t) \quad n_2(t) \quad \cdots \quad n_{N_r}(t)]^T$ is the additive noise vector. Furthermore, when we define the received signal matrix $\boldsymbol{X}$ whose column corresponds to the received data symbols at each time, it can be written by

$$\boldsymbol{X} = \boldsymbol{H}\boldsymbol{S} + \boldsymbol{N}, \tag{2}$$

$$\boldsymbol{S} = [\boldsymbol{s}(1) \quad \boldsymbol{s}(2) \quad \cdots \quad \boldsymbol{s}(N_s)] \in C^{N_t \times N_s}, \tag{3}$$

$$\boldsymbol{X} = [\boldsymbol{x}(1) \quad \boldsymbol{x}(2) \quad \cdots \quad \boldsymbol{x}(N_s)] \in C^{N_r \times N_s}, \tag{4}$$

$$\boldsymbol{N} = [\boldsymbol{n}(1) \quad \boldsymbol{n}(2) \quad \cdots \quad \boldsymbol{n}(N_s)] \in C^{N_r \times N_s}, \tag{5}$$

where N_s is the number of the symbols.

3. Signal Separation Method

3.1 LSCE

Let us denote the training symbols by $\hat{\boldsymbol{S}}$. The estimated MIMO channel matrix $\hat{\boldsymbol{H}}$ by the LSCE, which is one of the conventional equalizing techniques, is given by

$$\hat{\boldsymbol{H}} = \boldsymbol{X}\hat{\boldsymbol{S}}^H(\hat{\boldsymbol{S}}\hat{\boldsymbol{S}}^H)^{-1} \tag{6}$$

where ^{H} is the conjugate transpose. When the $\hat{\boldsymbol{H}}$ is estimated, the transmitted signals ($\boldsymbol{S}$) can be easily recovered by applying the (general) inverse of $\hat{\boldsymbol{H}}$ to the received signals.

3.2 ICA

When the transmitted signals from each antenna are mutually independent from each other, the transmitted signals can be restored from the observed signal by using the ICA.

Independent component matrix $\boldsymbol{Y}$ of the ICA is given by

$$\boldsymbol{Y} = \boldsymbol{W}\boldsymbol{X}, \tag{7}$$

$$\boldsymbol{Y} = [\boldsymbol{y}(1) \quad \boldsymbol{y}(2) \quad \cdots \quad \boldsymbol{y}(N_s)] \in C^{N_r \times N_s}, \tag{8}$$

$$\boldsymbol{W} = [\boldsymbol{w}_1 \quad \boldsymbol{w}_2 \quad \cdots \quad \boldsymbol{w}_{N_t}]^T \in C^{N_t \times N_r}, \tag{9}$$

In this report, we employ the FastICA [2] which is a popular technique as the ICA algorithm. The ICA is the method which can decompose mixed signals into individual signal components when the original signals are independent. The received signals have Gaussian distribution property than the original source signals. Therefore, when we obtain the weight matrix which maximizes the non-Gaussian property of the received signals, we can recover the transmitted signals by the matrix. As the criterion of non-Gaussian distribution, the kurtosis is often used. Absolute value of the kurtosis is maximum, non-Gaussian property of the signals becomes maximum. In other words, the ICA is the method which calculates the weight matrix $\boldsymbol{W}$ to maximize the absolute value of the kurtosis of $\boldsymbol{y}(t)$.

The FastICA is one of realization for the ICA by using a fast fixed-point algorithm, and it has fast convergence characteristic. Note that phase of evaluated channel matrix would be rotated by this algorithm. To compensate these phase ambiguity, a few training symbols is necessary even for the ICA.

4. Pre-ICA Filtering

The proposed pre-ICA filtering is the method applying the ICA to transmitting signals $\boldsymbol{S}$ to obtain suitable weight matrix which makes the streams independent even for short data stream. As a result, independency of transmitting signals becomes larger, and good BER can be realized. Figure 1 shows the flow chart of the pre-ICA filtering. $\boldsymbol{W}_t$ is the filter of the pre-ICA filtering, and $\boldsymbol{W}_r$ is the filter which apply ICA to receiving signals.

As shown in the flow chart ,first, we make transmitting signals $\boldsymbol{S}$. Then, we estimate suitable weight matrix $\boldsymbol{W}_t$ by using ICA, and apply the pre-ICA filter with $\boldsymbol{W}_t$ to transmitting signals $\boldsymbol{S}$. The transmitted signal is denoted as $\boldsymbol{S}'$. $\boldsymbol{S}'$ is affected by fading and we obtain receiving signals $\boldsymbol{X}$ at the receiver. Finally, we apply the ICA to receiving signals and demodulate them. We define this method as "proposed method 1".

The transmitted signal by "proposed method 1" are $\boldsymbol{S}'$. Therefore inverse of $\boldsymbol{W}_t$, ${\boldsymbol{W}_t}^{-1}$, should be required to recover original transmitted signal $\boldsymbol{S}$, not $\boldsymbol{S}'$, theoretically. This will be perfectly recover the signals and realize better BER performance. We define the method as "proposed method 2"(flow of dash line in figure 1 is added). Note that in this report ${\boldsymbol{W}_t}^{-1}$ is known at the receiver. In the next chapter, we evaluate these method by computer simulations.

5. Simulation Results

In the simulation, Rayleigh fading environment based on the Jakes model having 20 random scattering points is assumed. Received wave from each scattering point is assumed as a plane wave. The SNR in this report is defined by the ratio of overall transmitting power to noise. We considered a 2×2 MIMO system modulated by 64QAM.

Figure 2 shows the results of the number of the data symbols vs. BER. The number of training symbols is 32, and the SNR is 30 dB. As shown in this figure, BER of the proposed method 1 is better in a small number of data symbols than that of the conventional ICA. Furthermore the proposed method 2 shows superior performance to the proposed method 1. Therefore, it can be said that the pre-ICA filtering scheme for the proposed method 1,2 are effective with a few data symbols. Figure 3 shows the results of SNR vs. BER. In this simulation, the number of training symbols is 2, and the number of data symbols is

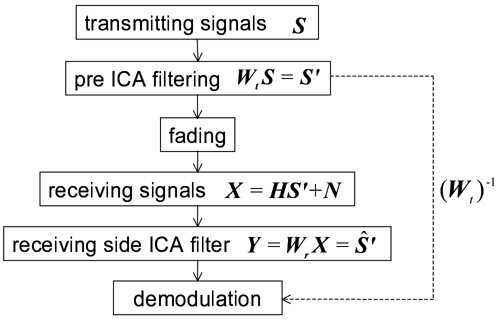

Figure 1: Flow chart of the pre-ICA filtering

256, that is to say both symbols are relatively small. As shown in the figure, even when the SNR is high, the performance cannot be improved by the LSCE. On the other hand, good and stable performance can be realized by the proposed method 2.

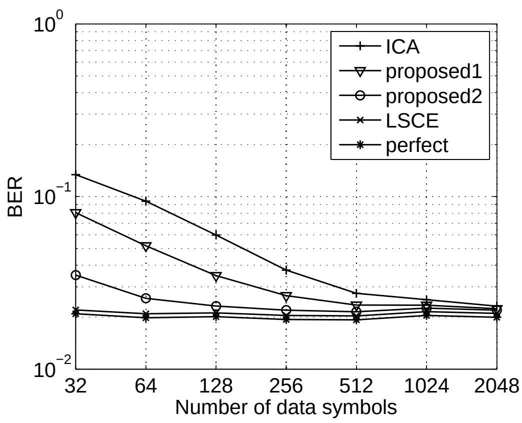

Figure 2: Number of data symbols vs. BER

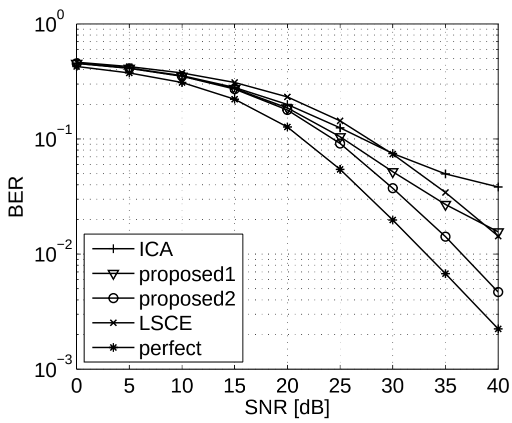

Figure 3: SNR vs. BER

6. Experimental Results of the MIMO Transmission

To verify the reliability of the computer simulation results, we performed indoor experiment of the MIMO transmission. The experiment was done in the environment as shown in figure 4. Location of the transmitting antennas (Tx) were fixed, and the receiving antennas (Rx) were moved on 15×15 points. Each receiving point is half wavelength intervals. Number of the transmitting antennas and the receiving antennas are two each other, and their height was 85 cm. Center frequency of the OFDM signal is 2.4 GHz band, and bandwidth is 10 MHz in this experiment. Channel information of 56 subcarrier were obtained per one receiving point. Therefore, we can obtain $15 \times 15 \times 56 = 12600$ channel information. We define the environment with metallic partition between the antennas as "NLOS", without the partition as "LOS". Figure 5 shows the cumulative distribution of channel information amplitude on each environment. Cumulative distribution of rayleigh fading is also plotted as a reference.

We have evaluated MIMO transmission property by using the obtained channel information by the experiment. Figure 6 shows the results of the number of data symbols vs. BER by using the data. The number of training symbols is 32, and the SNR is 30 dB. In this figure, the dashed line, solid line shows measured results of LOS , NLOS environment. As shown in this figure, BER of the proposed method is good with a small number of data symbols in comparison with that of the conventional ICA. Figure 7 shows the results of the SNR vs. BER. The number of training symbols is 2, and the number of data symbols is 256. When the SNR is high, good and stable performance can be realized by the proposed method 2. Therefore, the proposed method is also effective on real environment.

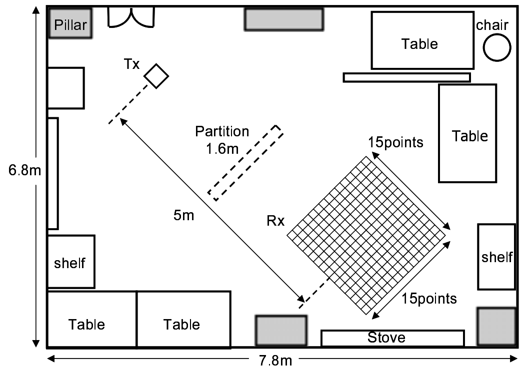

Figure 4: Indoor Environment

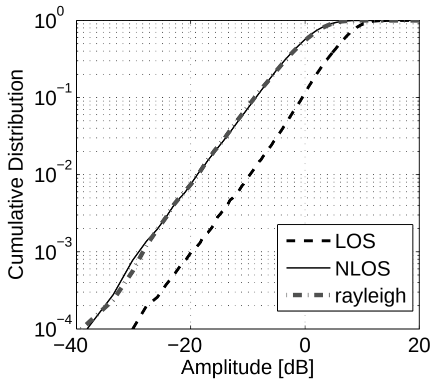

Figure 5: CDF

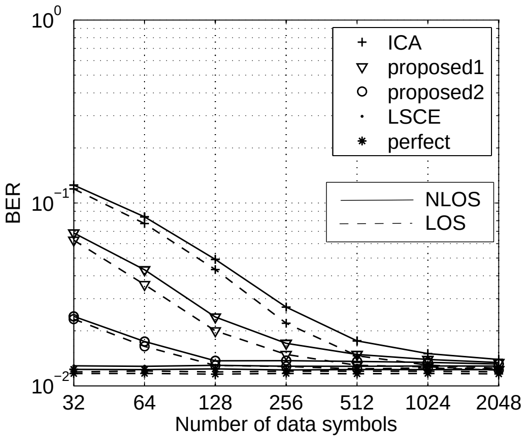

Figure 6: Number of data symbols vs. BER

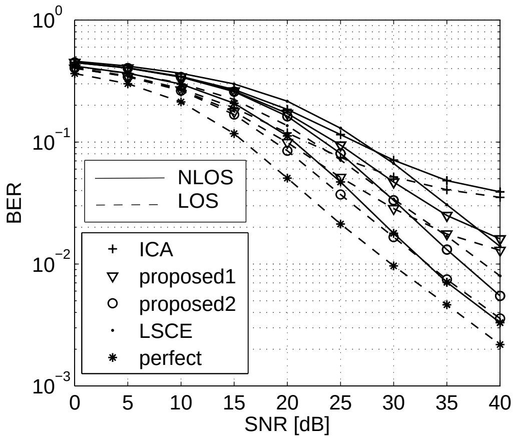

Figure 7: SNR vs. BER

7. Conclusions

In this report, we have shown performance of the blind MIMO transmission with the pre-ICA filter. BER property for 64QAM were evaluated by the computer simulation. These results show that the proposed method has advantages with transmission in a few data symbols in comparison with the LSCE. To realize the pre-ICA filtering denoted by "proposed method 2", we should transmit filter parameter to the receiver. Efficient parameter transmission scheme is one of the further problem.

Furthermore, we have examined the MIMO transmission by using experimental data, and shown the effectiveness of the pre-ICA filtering on real environment.

Acknowledgment

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References

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