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Single Antenna Relay System Using De-Noise and Forward Scheme for MIMO Transmission

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SUMMARY This paper proposes single antenna relay system using De-noise and forward (DNF) scheme for MIMO transmission. In this scheme, the relay node eliminates the noise by identifying constellation, and retransmits after amplification. DNF does not amplify the noise, and the channel information is unnecessary in the transmitting side. In this paper, we propose the de-noising scheme for MIMO application. Particularly, DNF can be used for the multi-stream transmission even though each relay nodes have single antenna. The simulation demonstrates the proposed scheme can improve the data transmission quality than the conventional scheme.

key words: *MIMO, Relay, DNF*

1. Introduction

MIMO (Multiple-Input Multiple-Output) transmission system has received a lot of attention as way of enhancing spectral efficiency [1]. MIMO system enables high-speed data transmission using spatial multiplexing by using multiple antennas. However, MIMO is not suitable for long-distance transmission. Because long-distance transmission limits the number of the available paths, and this affects the spatial multiplexing performance. A MIMO relay transmission system can be one of the candidates that solve this problem [2]. MIMO relay transmission enables enhancing spectral efficiency even for long distance data transmission.

AF (Amplify and Forward) and DF (Decode and Forward) have been commonly studied for the MIMO relay schemes [3], [4]. AF is the easiest transmission scheme in which relay node only amplifies received signals since it can be achieved with a simple configuration. Since this scheme enhances the noise, it causes deterioration in communication quality. DF is transmission scheme, in which the relay node retransmits after decoding the signal. It does not amplify the noise, but relay node needs multiple antennas corresponding to number of streams.

DNF (De-noise and Forward) is the transmission scheme where the relay node eliminates the noise by identifying constellation, and retransmits after amplification [5]. Before the data transmission, the relay node estimates ideal constellation points that do not contain the noise components. DNF does not amplify the noise, and the channel information is unnecessary in the transmitting side. Particularly, DNF can be used for the multi-stream transmission although each relay nodes have single antenna.

In this paper, a single antenna Relay transmission using DNF is proposed. It is shown DNF scheme can be used for the multi-stream transmission although each relay nodes have single antenna. Also, the transmitter does not need any additional pre-processing like a beam forming, and a channel information is unnecessary at the transmitter. The simulation demonstrates the proposed scheme can improve the data transmission quality than AF and DF.

2. Conventional Relay Method

In this section, conventional relay schemes, AF and DF are described. Figure 1 indicates the relay model in this paper. $\boldsymbol{H}_1$ and $\boldsymbol{n}_1$ are the channel and noise between the transmitter and the relay nodes. $\boldsymbol{H}_2$ and $\boldsymbol{n}_2$ are the channel and the noise between the relay nodes and the receiver. $\boldsymbol{G}$ is the gain of the relay nodes. When the channel from the transmitter to the receiver defined as $\boldsymbol{H}$, $\boldsymbol{H}$ can be written as

$$\boldsymbol{H} = \boldsymbol{H}_2\boldsymbol{G}\boldsymbol{H}_1. \tag{1}$$

When the transmit signal is defined as $\boldsymbol{x}$, the received signal $\boldsymbol{y}$ can be written as

$$\boldsymbol{y} = \boldsymbol{H}\boldsymbol{x} + \boldsymbol{H}_2\boldsymbol{G}\boldsymbol{n}_1 + \boldsymbol{n}_2. \tag{2}$$

Therefore, AF enhances $\boldsymbol{n}_1$, and increase error rate.

In the MIMO relay transmission, DF method can be recognized as a multi-user MIMO scheme. In Fig. 1, the channel from the transmitter to the relay node can be recognized as a down-link, and the channel from the relay node to the receiver can be recognized an up-link. If the relay node has no multi-antennas corresponding to the number of the streams, the relay node can not decode the received signal.

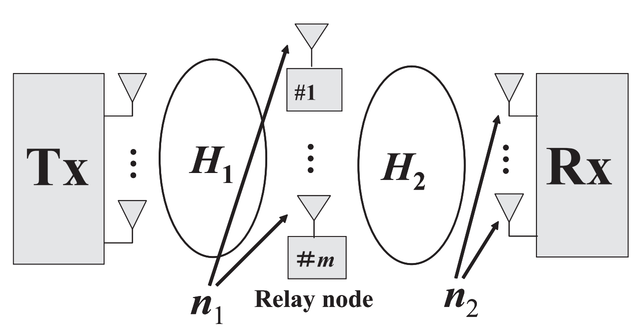

Fig. 1 System model.

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As a conventional method, BD (Brock Diagonalization) algorithm [6] is used at the transmitter. The transmitter make orthogonal beam to each relay node, and the relay node can decode and forward a single data stream. To make orthogonal beam, the transmitter has to acquire the channel information.

3. DE-Noising Scheme

In this section, the de-noising scheme is described. Figure 2 shows de-noising method in the relay node. First, the relay node estimates modulation scheme and ideal constellation of the transmit signal. In Fig. 2, ideal constellation point $\boldsymbol{s}_i$ is shown as

$$\boldsymbol{s}_i = \boldsymbol{H}_1 \boldsymbol{x}_i, \tag{3}$$

where $\boldsymbol{x}_i$ is training signal from the transmitter. When the number of the antennas at the transmitter is set to 2 and the QPSK modulation is used, $\boldsymbol{s}_i$ is 16 ideal constellation points each relay nodes. After that, the relay node receive transmit signal, and calculate a maximum posterior probability. This process corresponds to selecting the shortest Euclidean distance point in $\boldsymbol{s}_i$. The relay node selects the highest probability point, and reposition the received signal to the ideal signal. When the received signal at the relay node is defined as $\boldsymbol{r}$, $\boldsymbol{r}$ can be written as

$$\boldsymbol{r} = \boldsymbol{H}_1 \boldsymbol{x} + \boldsymbol{n}_1. \tag{4}$$

And when $\boldsymbol{n}_1$ is Gaussian, de-noised signal $\boldsymbol{s}$ is shown as

$$\boldsymbol{s} = \arg\min\{\|\boldsymbol{r} - \boldsymbol{s}_i\|^2\}. \tag{5}$$

That is, the relay node identifies constellation by repositioning the received signal to the nearest ideal point. After that, the relay node transmits after amplification. The received signal at the receiver $\boldsymbol{y}$ can be written as

$$\boldsymbol{y} = \boldsymbol{H}_2 \boldsymbol{G} \boldsymbol{s} + \boldsymbol{n}_2. \tag{6}$$

As indicated by the (6), the relay nodes de-noise $\boldsymbol{n}_1$. This scheme does not amplify the noise, and can be achieved by using single antenna at the relay nodes.

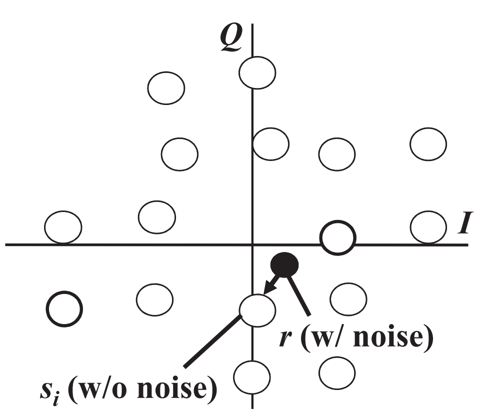

Fig. 2 De-noising method.

4. Simulation

In this section, BER (Bit Error Rate) of the proposed scheme is simulated. In the simulation, the number of the relay node is set to m, and each relay node has one antenna. The channel is i.i.d. (Independent and Identically-Distributed), and white Gaussian noise assumed. It is assumed the transmitter and receiver do not communicate directly. The number of the antennas at the transmitter and receiver are set to 2. In the relay node, the amplification gain $\boldsymbol{G}$ is set equally to the propagation loss between the transmitter and relay node. The QPSK modulation is used in this simulation.

The actual example of the de-noising process is shown in Fig. 3. In these figures, circle markers are ideal constellation, and cross markers are the constellation including the noise. (a) shows the constellation that before de-noising, and (b) is the constellation after de-noising. Like these figures, de-noising is achieved. And as described in the previous section, the relay node can successfully eliminate the noise. The ideal constellation depends on the channel. If the ideal points are separated sufficiently, the relay node can de-noise correctly. To different the channel each relay node, increasing the relay node improve communication quality.

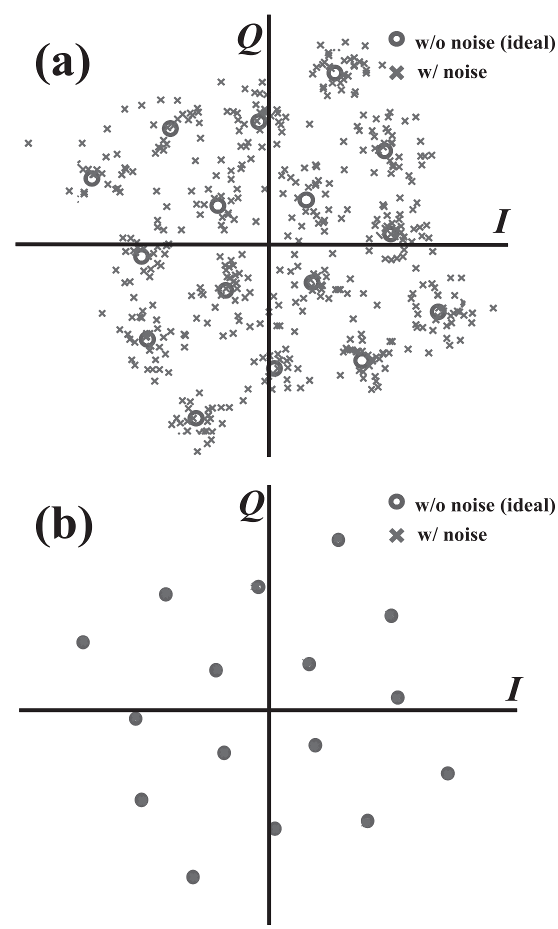

Fig. 3 Example of constellation.

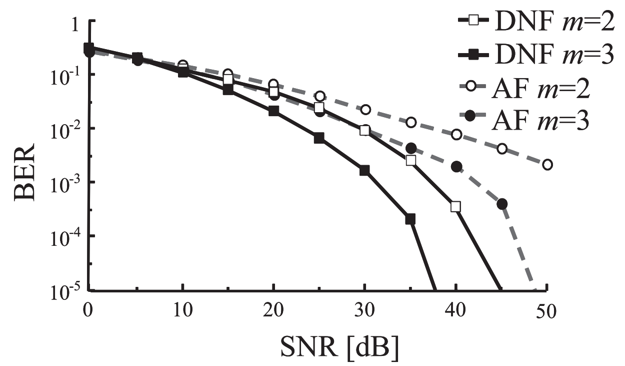

Fig. 4 BER of AF and DNF.

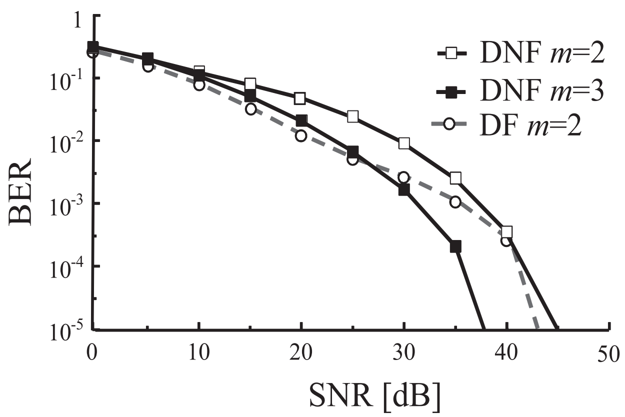

Fig. 5 BER of DF and DNF.

Figure 4 shows BER of AF and DNF when $m = 2$ and 3. By increasing the number of the relay node, the receiver can decode more accurately. When we focus on the SNR at BER = 10^{-3} and m is 3, DNF scheme can lower the required SNR by 10 dB compared with AF.

Figure 5 shows BER characteristics that compare the performance of DF and DNF when $m = 2$ and 3. Here, for DF, BD algorithm is applied. BD algorithm can not increase the relay node than the number of stream because the transmitter can not make orthogonal beam. In contrast, DNF can reduce error rate by increasing the relay node. When we focus on the SNR at BER $=10^{-3}$, the DNF with $m = 3$ can lower the required SNR by 4 dB compared with the DF when m is 2.

5. Conclusion

The relay scheme employing DNF has been proposed in this paper. In this scheme, the relay node eliminates the noise by identifying constellation, and retransmits after amplification. When we focus on the SNR at BER $=10^{-3}$, DNF can lower the required SNR by 10 dB compared with AF. Also, DNF can lower the required SNR by 4 dB compared with DF. From the simulation results, it is found that BER can be improved by proposed scheme, and this indicates DNF with the single antenna enables high-quality transition even for MIMO systems.

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