2B2-5

A new eigenvector beam-forming method without first eigenvector for reducing interference inside relay station

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1 Introduction

In recent wireless communications, communication with wider service area and high data rate is required by the spread of mobile phones and wireless LAN systems. Moreover, wireless communication becomes a very important tool: hence, it must be reliable when disasters, and on on occur. From the viewpoint of decreasing the transmission power and expanding the service area, relay stations are investigated regardless of mobile and fixed wireless communications. Moreover, MIMO transmission using the relay station, *Relay MIMO transmission* is proposed from the viewpoint of a high frequency utilization and reliable communication [1].

Decode-and-Forward (DF) scheme [2], which uses two time slots for one transmission, is generally adopted when considering the relay station. However, frequency/time resource becomes half when the DF is used. Therefore, simultaneous transmission and reception at the relay station is ideal. However, interference with a extremely higher power than a desired signal arrives at the receiver at the relay station when the simultaneous transmission and reception is employed inside the relay station. The interference between the transmitter and receiver at the relay station should be solved by multiple technologies which are directional/dual-polarization antennas, de-coupling circuit and signal processing, and so on, because the interference power must be reduced from 80 to 100 dB.

As a basic study in this paper, we propose and evaluate the interference cancellation method inside relay station by a signal processing technique. A new eigenvector beam-forming method without first eigenvector for efficiently reducing interference is proposed. In the proposed method, propagation characteristics of Short-Range MIMO (SR-MIMO) [3] are utilized. In this paper, a basic idea of the proposed method is described and the effectiveness of the proposed method is shown by numerical calculations.

2 Proposed method

Figure 1 denotes a proposed configuration of relay station for simultaneous transmission and reception. As shown in Figure 1, the eigenvector beamforming without eigenvector corresponding with 1st eigenvalue is employed at the relay station, in order to reduce the interference from the transmitter to the receiver at the relay station.

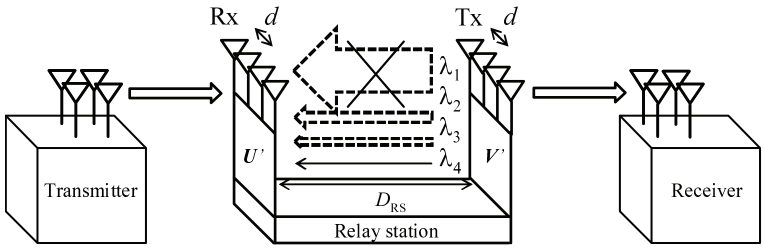

Figure 1: Proposed configuration of relay station for simultaneous transmission and reception.

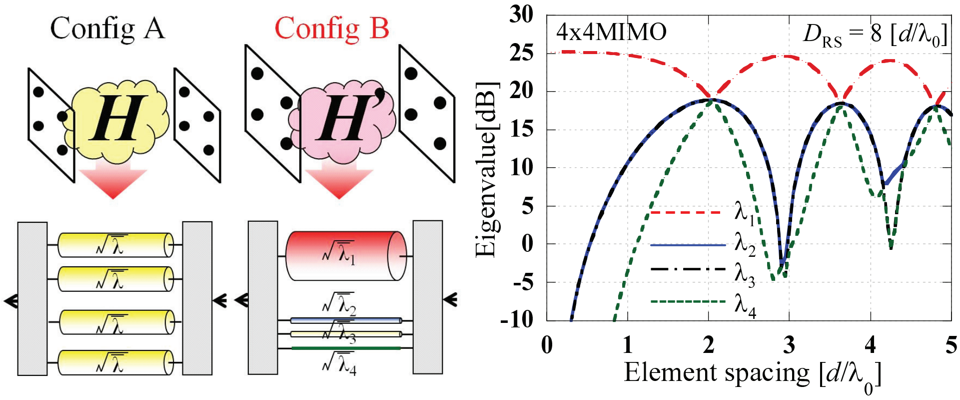

Figure 2: Typical propagation characteristics in Short-Range MIMO

Figure 2 denotes two tyipical propagation characteristics on the SR-MIMO to explain the key point of the proposed method. In Figure 2, 4×4 MIMO transmission is considered, and the transmission distance between the transmitter and receiver, D_{RS} is 8 d/λ_0. As shown in Figure 2, SR-MIMO transmission has an optimum element spacing that all eigenvalues which are obtained by the correlation matrix of the channel matrix are identical ($d = 2.0\ \lambda_0$ in Figure 2). This antenna configuration is called Config.A in Figure 2. On the other hand, there is the element spacing that eigenvelues except 1st eigenvalue is much smaller than 1st eigenvalues ($d = 2.9\ \lambda_0$ in Figure 2). This antenna configuration is called Config.B. In this case, as shown in Figure 2, since the channel capacity of Config.A is maximum and that of Config.A is minimum, Config.A should be used in the SR-MIMO. On the other hand, there is a chance to utilize Config.B when considering the interference reduction at the relay station. We propose the eigenvector beamforming without 1st eigenvector corresponding 1st eigenvalue. Figure 3 shows the eigenvector beamforming without 1st eigenvector for Config.A and B. Eigenvectors except 1st eigenvector $\boldsymbol{V'}$ and $\boldsymbol{U'}$ are used the weights of transmitter and receiver at the relay station, respectively. By employing this beamforming for Config.B, the efficient interference reduction is expected to be realized because the eigenvalues expect 1st eigenvalue are very smaller than 1st eigenvalues in Config.B while the interference is not reduced so much when considering Config.A. To confirm the possibility of the proposed method, we define the interfering power reduction, IPR is defined as,

$$\mathrm{IPR} = \sum_{i=1}^{L} \lambda_i / \sum_{k=2}^{L} \lambda_k \tag{1}$$

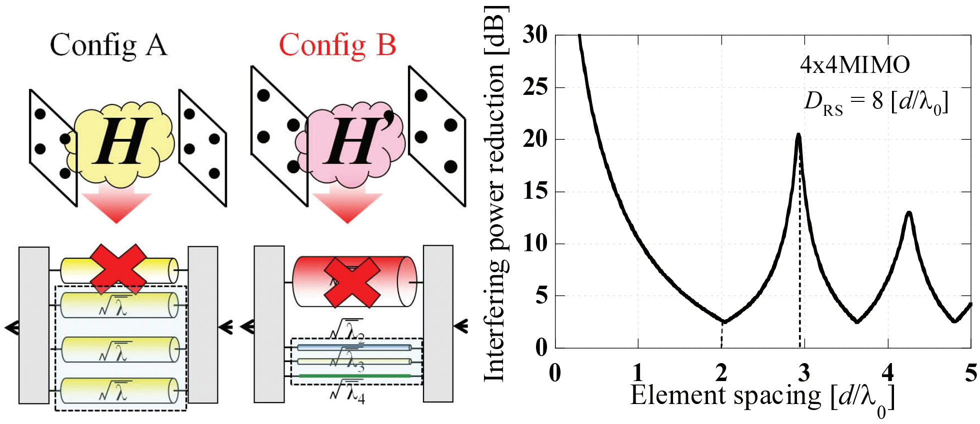

Figure 3: Comparison of the interference removal characteristic in configuration A and B

Table 1: Simulation conditions

Number of transmit and receive antennas, (M, N)	$(M, N) = (4, 4), (9, 9), (16, 16)$
Distance between transmission and reception, D_{RS}	$3 \leq D_{RS} \leq 50$ $[d/\lambda_0]$
Element spacing, d	$1 \leq d \leq 20$ $[d/\lambda_0]$

where λ_i denotes i-th eigenvalue and L is the number of eigenvalues. As shown in Figure 3, Only 2 dB interference reduction is obtained by Config.A ($d = 2.0\lambda_0$). On the other hand, it is possible to reduce the interference of about 20 dB by Config.B (d $= 2.9\lambda_0$). Hence, it is shown that the proposed method can utilize the condition which is the worst case when considering the SR-MIMO transmission.

3 Interference reduction characteristics by the proposed method

Numerical calculations are employed in order to clarify the element spacing suitable for the proposed method. Table 1 shows the simulation conditions. The element spacing is set to be greater than $1\lambda_0$ to avoid the condition that very narrow element spacing is selected.

Figure 4 shows the eigenvalues versus element spacing when D_{RS} is 33λ. The results of 4×4 and 9×9 MIMO are plotted in these figure. 2-diemnsional arrays (2D-

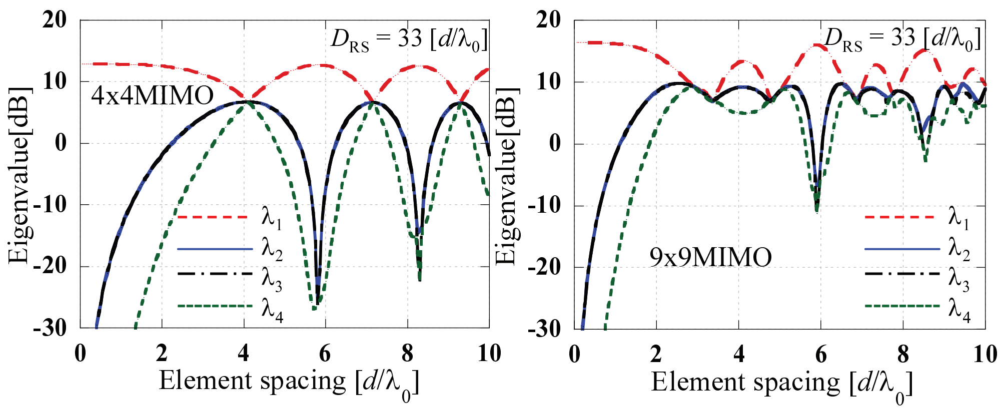

Figure 4: 1st to 4th eigenvalues versus element spacing

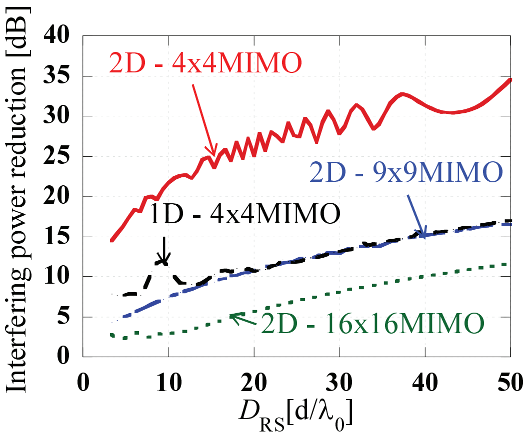

Figure 5: Interfering power reduction (IPR) versus transmit distance.

arrays) are placed at both transmitter and receiver. For SR-MIMO transmission, the optimal element spacing is $4\lambda_0$. On the other hand, eigenvalues except 1st eigenvalue are smallest with $d = 5.8\lambda_0$ and $5.9\lambda_0$, respectively, when 4×4 and 9×9 MIMO transmissions are employed. When 4×4 MIMO ($d = 5.8\lambda_0$) and 9×9 MIMO ($d = 5.9\lambda_0$) are compared, IPRs are 29.6 and 13.8 dB, respectively. Hence, it is shown that higher IPR is obtained by 4×4 MIMO than that by 9×9 MIMO.

Figure 5 shows the IPR when MIMO is 4×4, 9×9 and 16×16 MIMO with 2D-arrays. Linear array (1D-array) with 4×4 MIMO is also evaluated. As shown in Figure 5, when 2D-arrays for 4×4 and MIMO 9×9 MIMO are used, the IPRs are 27.6 and 11.8 dB when $D_{RS} = 25\lambda_0$. Hence, it is difficult to obtain high IPR when antenna elements are increased. It is also clarified that 2D-array is suitable to obtain higher IPR compared to 1D-array when 4×4 MIMO is considered. Moreover, 4×4 MIMO with 2-D array obtains the IPR of more than 30 dB when D_{RS} is larger than $28.7\lambda_0$.

4 Conclusion

In this paper, the eigenvector beam-forming method without first eigenvector for efficiently reducing interference is proposed. In the proposed method, the propagation characteristics of SR-MIMO are utilized. By the numerical calculation, it is shown that interference reduction over 30 dB is achieved by using appropriate element spacing when 4×4MIMO transmission with 2-D array is employed.

Aknowledgement

The part of this work is supported by Adaptable and Seamless Technology Transfer Program (A-STEP), JST.

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