User-driven Suboptimal Joint Transmit-receive Diversity in Asymmetric MIMO Fading Channel

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***Abstract*—Joint transmit-receive diversity (JTRD) is expected to significantly improve the transmission performance in a multi-input multi-output (MIMO) fading channel. In practical situations, the number of base station (BS) antennas is much larger than that of user equipment (UE) antennas, resulting in an asymmetric MIMO fading channel. In this paper, a practical user-driven suboptimal JTRD scheme assuming time division duplex (TDD) in such an asymmetric MIMO fading channel is investigated. In a user-driven suboptimal JTRD scheme, firstly the user equipment (UE) determines its diversity weight vector, and then, BS determines its diversity weight vector so as to maximize the resulting composite channel gain for the given UE diversity weight vector. While the optimal JTRD jointly optimizes the diversity weight vectors at BS and UE by solving the eigen-equations composed of MIMO channel matrix. In principle, the user-driven suboptimal JTRD provides lower diversity gain than the optimal JTRD. In this paper, it is shown by numerical link capacity evaluation that in an asymmetric MIMO fading channel, where the number of BS antennas is much larger than that of UE antennas, the use of selection diversity in user-driven suboptimal diversity provides a slightly higher diversity gain than the use of maximal-ratio diversity and that the link capacity gap between the user-driven suboptimal JTRD and the optimal JTRD becomes quite small.**

Keywords—Joint transmit-receive diversity, MIMO fading channel

I. Introduction

The spatial diversity technique has been recognized a long time as a powerful technique for improving the transmission performance in a multipath fading channel [1]. The diversity technique can be employed at the transmitter and/or the receiver. The maximal-ratio combining (MRC), the equal-gain combining (EGC), and the selection combining (SC) are well-known as the receive diversity technique [1]. Known as the transmit diversity technique is the maximal-ratio transmission (MRT) [2]. If both transmitter and receiver are equipped with multiple antennas, the use of joint transmit-receive diversity (JTRD) significantly improves the transmission performance in a multi-input multi-output (MIMO) fading channel.

If the transmitter and receiver diversity weight vectors are jointly optimized so as to maximize the resulting composite channel gain, this diversity scheme is called optimal JTRD in this paper. The maximal-ratio transmission and combining (MRTC) [3], [4] is a kind of optimal JTRD. In [3], optimal diversity weight vectors were derived for 2×2 MIMO fading channel case. In [4], the probability density function (PDF) of the received signal-to-noise ratio (SNR) achievable by MRTC was derived for the case of an arbitrary number of transmit antennas and 2 receive antennas. An optimal pair of diversity weight vectors for the general $N\times M$ MIMO channel case, where N and M are arbitrary numbers, can be obtained by solving eigen-equations composed of MIMO channel matrix [5]. In [5], closed-form expressions for the transmit and receive diversity weight vectors and for the resulting received SNR were derived for $2\times M$ MIMO channel case. Note that the optimal JTRD is equivalent to the maximum eigenmode beamforming [6].

Rather than solving the eigen-equations, another type of JTRD is possible, in which firstly either the transmitter or the receiver determines its diversity weight vector based on either maximal-ratio or selection principle, and then, conditioned on this diversity weight vector, the other side determines its diversity weight vector so as to maximize the resulting composite channel gain. Such a diversity scheme is called suboptimal JTRD in this paper. Although in principle, the suboptimal JTRD provides lower diversity gain than the optimal JTRD, the suboptimal JTRD is practical since solving the eigen-equations is not required.

It is desirable to equip both transmitter and receiver with as many antennas as possible regardless of optimal JTRD or suboptimal JTRD. The base station (BS) has relatively sufficient space to equip a large number of antennas. However, due to its space limitation and hardware complexity limitation, user equipment (UE) may be able to equip only a few antennas. Therefore, in practical situations, the number of BS antennas is much larger than that of UE antennas, resulting in an asymmetric MIMO fading channel. In this paper, a practical user-driven suboptimal JTRD scheme assuming time division duplex (TDD) in such an asymmetric MIMO fading channel is investigated.

In a user-driven suboptimal JTRD scheme, UE firstly determines its diversity weight vector based on either maximal-ratio or selection diversity principle, and then, BS determines its diversity weight vector so as to maximize the resulting composite channel gain for the given UE diversity weight vector. Interesting questions on the user-driven suboptimal JTRD in an asymmetric MIMO fading channel are which diversity principle, selection or maximal-ratio, provides higher diversity gain and how much the achievable diversity gain is inferior compared to the optimal JTRD. In this paper, we try to give answers to these questions.

In this paper, the downlink (BS to UE) transmission of user-driven suboptimal JTRD is considered although user-driven suboptimal JTRD can be applied to the uplink (UE to BS) transmission assuming TDD. Closed-form received SNR expressions are derived for user-driven suboptimal and optimal JTRD schemes. In this paper, the MIMO Rayleigh fading channel often encountered in a rich scattering environment is assumed. It is shown by link capacity evaluation using the derived closed-form received SNR expressions that, interestingly, when the number of BS antennas is fairly large, the selection diversity provides a slightly higher diversity gain than the maximal-ratio diversity and the link capacity gap between the user-driven suboptimal JTRD and the optimal JTRD becomes quite small.

It should be noted that this paper is focused on the spatial diversity effect of user-driven JTRD by considering the single-user environment. Meanwhile, MIMO multiplexing [7] has been recognized as an indispensable technique for efficiently utilizing the limited bandwidth and was extensively studied [8-14]. The user-driven JTRD in the multi-user environment is left for our future study.

The rest of the paper is organized as follows. User-driven suboptimal JTRD using either maximal-ratio or selection diversity is described in Sect. II. Closed-form received SNR expressions are derived for user-driven suboptimal JTRD and optimal JTRD. In Sect. III, the received SNR comparison is made between maximal-ratio diversity and selection diversity in the user-driven suboptimal JTRD. In Sect. IV, the link capacities achievable by user-driven suboptimal JTRD and optimal JTRD are evaluated and compared assuming an asymmetric MIMO Rayleigh fading channel. Sect. V offers some concluding remarks and future studies.

Throughout the paper, $[.]^T$, $[.]^H$, $[.]^*$, $E[.]$, and $\|.\|_2$ represent the transpose, Hermitian transpose, complex conjugate, ensemble average, and Frobenius norm operations, respectively.

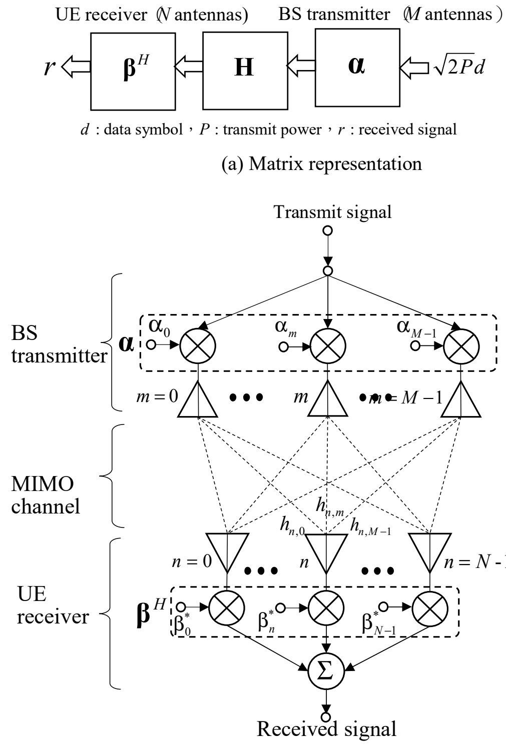
II. PRINCIPLE OF SUBOPTIMAL JTRD

The downlink (BS to UE) transmission model of suboptimal JTRD is illustrated in Fig. 1. The diversity weight vectors of BS transmitter and UE receiver are respectively denoted by $\boldsymbol{\alpha}=\left[\alpha_0 \;\cdots\; \alpha_m \;\cdots\; \alpha_{M-1}\right]^T$ and $\boldsymbol{\beta}=\left[\beta_0 \;\cdots\; \beta_n \;\cdots\; \beta_{N-1}\right]^T$, where $\|\boldsymbol{\alpha}\|_2^2=\|\boldsymbol{\beta}\|_2^2=1$. The MIMO channel matrix is denoted by $\mathbf{H}=\left[\mathbf{h}_0 \;\cdots\; \mathbf{h}_m \;\cdots\; \mathbf{h}_{M-1}\right]$, where $\mathbf{h}_m=\left[h_{0,m}\cdots h_{n,m}\cdots h_{N-1,m}\right]^T$ with $h_{n,m}$ representing the complex-valued channel gain between BS antenna m(=0~M-1) and UE antenna n(=0~N-1). Rayleigh fading is assumed, but the pathloss and shadowing loss encountered in wireless communications are not considered here. $\{h_{n,m}\}$ are independent zero-mean complex-valued Gaussian variables, each having a unit variance, i.e., $E[h_{n,m}]=0$ and $E[|h_{n,m}|^2]=1$.

The signals to be transmitted from M antennas of BS can be expressed in the vector form as $\sqrt{2P}\boldsymbol{\alpha}d$, where P and d represent the transmit power and the transmit data symbol, respectively. The received signal r after receive diversity combining at UE is given in the equivalent lowpass representation form as

$$r=\sqrt{2P}\left(\boldsymbol{\beta}^H\mathbf{H}\boldsymbol{\alpha}\right)d+\boldsymbol{\beta}^H\mathbf{n}, \tag{1}$$

where $\mathbf{n}$ represents the received noise vector of size N with each element being characterized by an independent zero-mean complex-valued Gaussian variable with variance σ^2. In Eq. (1), $\boldsymbol{\beta}^H\mathbf{H}\boldsymbol{\alpha}$ is the composite channel gain when JTRD is used.



(a) Matrix representation

(b) Transmitter/receiver structure

Fig. 1 Downlink transmission model of suboptimal JTRD.

In this paper, we consider the user-driven suboptimal JTRD, in which UE determines $\boldsymbol{\beta}$ first based on the channel information $\mathbf{H}$. Then, UE transmits a pilot precoded by using $\boldsymbol{\beta}$ to BS. Upon the reception of the precoded pilot transmitted from UE, BS determines its diversity weight vector $\boldsymbol{\alpha}$. The equivalent channel between M-antenna BS and N-antenna UE is given as $\boldsymbol{\beta}^H\mathbf{H}$. The BS diversity vector $\boldsymbol{\alpha}$, which maximizes the composite channel gain $\boldsymbol{\beta}^H\mathbf{H}\boldsymbol{\alpha}$ for the given $\boldsymbol{\beta}$, is given as the well-known maximal-ratio diversity weight vector [1], i.e., $\boldsymbol{\alpha}=(\boldsymbol{\beta}^H\mathbf{H})^H/\|\boldsymbol{\beta}^H\mathbf{H}\|_2$. As a consequence, the composite channel gain $\boldsymbol{\beta}^H\mathbf{H}\boldsymbol{\alpha}$ of such a user-driven suboptimal JTRD becomes

$$\boldsymbol{\beta}^H\mathbf{H}\boldsymbol{\alpha}=\|\boldsymbol{\beta}^H\mathbf{H}\|_2. \tag{2}$$

BS can acquire the knowledge of equivalent channel $\boldsymbol{\beta}^H\mathbf{H}$ by transmitting the known pilot d_p from UE. The pilot received by BS is given as $(\boldsymbol{\beta}^H\mathbf{H})^H d_p$, from which BS can acquire $\boldsymbol{\beta}^H\mathbf{H}$ and then, can determine $\boldsymbol{\alpha}$.

It is noted that N-antenna UE can be viewed by BS as a virtual single-antenna UE. Therefore, BS does not need to know how many antennas UE is equipped with. Accordingly, this user-driven suboptimal JTRD can be considered practical. This is an important feature of suboptimal JTRD, particularly in the case of multiuser environment where various UEs each having a different number of antennas exist. BS can consider all UEs to be virtual single-antenna UEs. In this paper, the single-user environment is considered. Performance comparison of user-driven suboptimal and optimal JTRD schemes in a multiuser environment is left as our future study.

A. Diversity weight vectors $(\boldsymbol{\alpha}, \boldsymbol{\beta})$

The principle of user-driven suboptimal JTRD using either maximal-ratio or selection diversity is illustrated in Fig. 2.

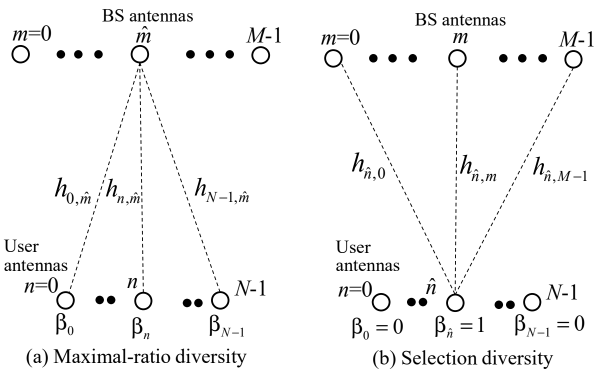


Fig. 2 Principle of user-driven suboptimal JTRD. UE diversity weight vector is determined first.

In the case of maximal-ratio diversity, UE identifies the best BS antenna $\hat{m}$ which maximizes $\sum_{n=0}^{N-1}|h_{n,m}|^2$ and then, obtains its diversity weight vector $\boldsymbol{\beta}$, which is equivalent to the maximal-ratio diversity conditioned on the transmitter antenna $\hat{m}$. Instead of maximal-ratio diversity, the use of selection diversity may be a good choice in practice since the selection diversity requires less hardware and signal processing complexity than the maximal-ratio diversity. In user-driven suboptimal JTRD using selection diversity, UE identifies its best antenna $\hat{n}$ which maximizes $\sum_{m=0}^{M-1}|h_{n,m}|^2$ and uses it among N antennas.

The diversity weight vector $\boldsymbol{\beta}$ for the above user-driven suboptimal JTRD is given as

$$\boldsymbol{\beta} = \begin{cases} \dfrac{[h_{0,\hat{m}} \cdots h_{n,\hat{m}} \cdots h_{N-1,\hat{m}}]^T}{\sqrt{\sum_{n=0}^{N-1}|h_{n,\hat{m}}|^2}} \text{ for maximal-ratio diversity} \\ \qquad \text{where } \hat{m} = \arg\max_m \sum_{n=0}^{N-1}|h_{n,m}|^2 \\ [\beta_0 \cdots \beta_n \cdots \beta_{N-1}]^T \quad \text{for selection diversity} \\ \qquad \text{where } \hat{n} = \arg\max_n \sum_{m=0}^{M-1}|h_{n,m}|^2 \\ \qquad \text{and } \beta_n = 1(0) \text{ if } n = \hat{n} \text{ (else)} \end{cases}. \quad (3)$$

$\boldsymbol{\alpha}$, which maximizes the composite channel gain $\boldsymbol{\beta}^H \mathbf{H} \boldsymbol{\alpha}$ for the given $\boldsymbol{\beta}$, is given as

$$\boldsymbol{\alpha} = \left(\boldsymbol{\beta}^H \mathbf{H}\right)^H \Big/ \left\|\boldsymbol{\beta}^H \mathbf{H}\right\|_2$$
$$= \begin{cases} \left[\left(\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,0}\right) \cdots \left(\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,m}\right) \cdots \left(\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,M-1}\right)\right]^H \Big/ \sqrt{\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,m}\right|^2} \\ \qquad \text{for maximal-ratio diversity} \\ \left[h_{\hat{n},0} \cdots h_{\hat{n},m} \cdots h_{\hat{n},M-1}\right]^H \Big/ \sqrt{\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^2} \\ \qquad \text{for selection diversity} \end{cases}. \quad (4)$$

B. Received SNR

The composite channel gain $\boldsymbol{\beta}^H \mathbf{H} \boldsymbol{\alpha}$ obtainable by user-driven suboptimal JTRD can be derived from Eq. (2). Since $\boldsymbol{\beta}^H \mathbf{H} = \left\|\boldsymbol{\beta}^H \mathbf{H}\right\|_2 \boldsymbol{\alpha}^H$ and $\boldsymbol{\alpha}^H \boldsymbol{\alpha} = 1$, we obtain

$$\boldsymbol{\beta}^H \mathbf{H} \boldsymbol{\alpha} = \left\|\boldsymbol{\beta}^H \mathbf{H}\right\|_2 = \begin{cases} \sqrt{\dfrac{\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,m}\right|^2}{\sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^2}} & \text{for maximal-ratio diversity} \\ \sqrt{\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^2} & \text{for selection diversity} \end{cases}. \quad (5)$$

From Eq. (5), the received SNR γ is expressed as

$$\gamma = \Gamma \left\|\boldsymbol{\beta}^H \mathbf{H}\right\|_2^2 = \begin{cases} \Gamma \sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h^*_{n,\hat{m}} h_{n,m}\right|^2 \Big/ \sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^2 \\ \qquad \text{for maximal-ratio diversity} \\ \Gamma \sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^2 \quad \text{for selection diversity} \end{cases}, \quad (6)$$

where

$\hat{m} = \arg\max_m \sum_{n=0}^{N-1}\left|h_{n,m}\right|^2$ and $\hat{n} = \arg\max_n \sum_{m=0}^{M-1}|h_{n,m}|^2$. Γ represents the transmit SNR given by P/σ^2.

III. Comparison between Maximal-ratio Diversity and Selection Diversity in User-driven Suboptimal JTRD

The maximal-ratio diversity provides higher diversity gain than the selection diversity [1]. This is valid only when $M \approx N$. We consider an asymmetric MIMO channel, where the number of BS antennas is fairly large compared to that of UE antennas, i.e., $M \gg N$. We will show below that assuming such a strongly asymmetric MIMO channel, the user-driven suboptimal JTRD using selection diversity provides slightly higher composite channel gain than using maximal-ratio diversity.

The composite channel gain of the user-driven suboptimal JTRD using maximal-ratio diversity is given by Eq. (6). $\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m}\right|^{2}$ in Eq. (6) can be rewritten as

$$\begin{aligned}\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m}\right|^{2} &= \sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\sum_{n'=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m} h_{n',m} h_{n',\hat{m}}^{*} \\ &= \sum_{n=0}^{N-1}\sum_{n'=0}^{N-1} h_{n,\hat{m}}^{*} h_{n',m}\left(\sum_{m=0}^{M-1} h_{n',\hat{m}}^{*} h_{n,m}\right)\end{aligned} . \qquad (7)$$

Both $h_{n',\hat{m}}$ and $h_{n,m}$ are zero-mean complex-valued Gaussian variables having unit variance. Therefore, as M becomes fairly large (i.e., $M \gg N$), $\sum_{m=0}^{M-1} h_{n',\hat{m}}^{*} h_{n,m}$ in Eq. (7) approaches 0 if $n' \neq n$ according to the law of large numbers. As a consequence, we have

$$\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m}\right|^{2} \approx \sum_{n=0}^{N-1}\left(\left|h_{n,\hat{m}}\right|^{2}\left(\sum_{m=0}^{M-1}\left|h_{n,m}\right|^{2}\right)\right). \qquad (8)$$

Since

$$\sum_{m=0}^{M-1}\left|h_{n,m}\right|^{2} \leq \sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^{2} , \qquad (9)$$

Eq. (8) becomes

$$\begin{aligned}\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m}\right|^{2} &\approx \sum_{n=0}^{N-1}\left(\left|h_{n,\hat{m}}\right|^{2}\left(\sum_{m=0}^{M-1}\left|h_{n,m}\right|^{2}\right)\right) \\ &\leq \sum_{n=0}^{N-1}\left(\left|h_{n,\hat{m}}\right|^{2}\left(\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^{2}\right)\right) \\ &= \left(\sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^{2}\right)\left(\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^{2}\right)\end{aligned}. \qquad (10)$$

Finally, we obtain the following relationship between user-driven suboptimal JTRD schemes using maximal-ratio diversity and using selection diversity with respect to the composite channel gain:

$$\begin{aligned}\boldsymbol{\beta}^{H}\mathbf{H}\boldsymbol{\alpha}\,|_{\text{maximal-ratio}} &= \sqrt{\frac{\sum_{m=0}^{M-1}\left|\sum_{n=0}^{N-1} h_{n,\hat{m}}^{*} h_{n,m}\right|^{2}}{\sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^{2}}} \\ &\leq \sqrt{\frac{\left(\sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^{2}\right)\left(\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^{2}\right)}{\sum_{n=0}^{N-1}\left|h_{n,\hat{m}}\right|^{2}}} = \sqrt{\sum_{m=0}^{M-1}\left|h_{\hat{n},m}\right|^{2}} , \\ &= \boldsymbol{\beta}^{H}\mathbf{H}\boldsymbol{\alpha}\,|_{\text{selection}}\end{aligned} \qquad (11)$$

from which, it can be found that, when $M \gg N$, the selection diversity provides higher received SNR than the maximal-ratio diversity, i.e., $\gamma_{\text{maximal-ratio}} \leq \gamma_{\text{selection}}$. This condition can be satisfied in many practical situations.

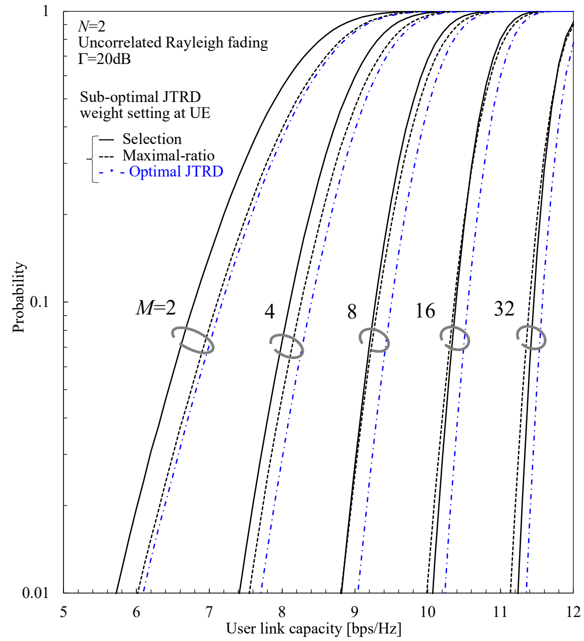
IV. Link Capacity Evaluation

In Sect. III, it has been shown that, when $M \gg N$, the selection diversity provides higher received SNR than the maximal-ratio diversity and accordingly, the user-driven suboptimal JTRD using selection diversity provides higher link capacity than using maximal-ratio diversity. Below, this is confirmed by the link capacity evaluation.

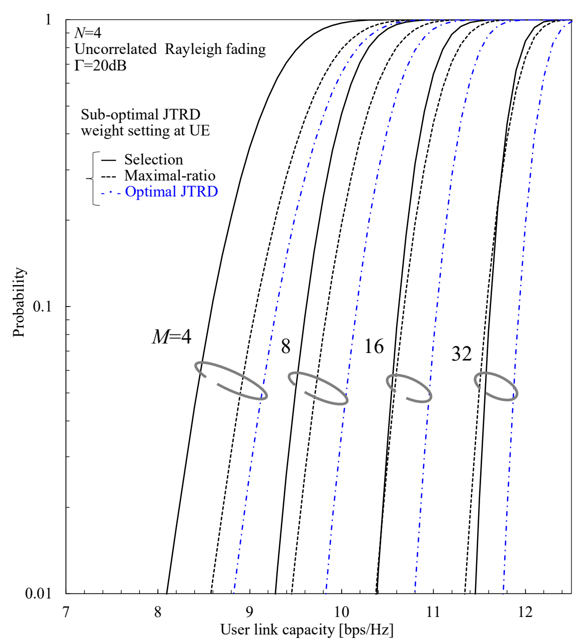
We assume that BS has M (=2~32) antennas while UE has N=2, 4 antennas. Assuming a rich scattering environment with non-line-of-sight path, Rayleigh faded channel gains $\{h_{n,m}; n=0\sim 1, m=0\sim M-1\}$ are uncorrelated. Furthermore, pathloss and shadowing loss are not considered.

The link capacity C [bps/Hz] achievable by the user-driven suboptimal JTRD is evaluated by the Monte-Carlo computation method using $C=\log_2(1+\gamma)$, where $\gamma\ (=\Gamma\left|\boldsymbol{\beta}^{H}\mathbf{H}\boldsymbol{\alpha}\right|^{2})$ is given by Eq. (6) and the average received SNR Γ is set to 20dB. The cumulative distribution function (CDF) of the achievable link capacity is plotted in Fig. 3 when N=2 and 4. It can be seen from the figure that when the MIMO channel is symmetric, e.g. M=N=2 and 4, the maxima-ratio diversity provides higher link capacity than the selection diversity. However, its advantage over the selection diversity diminishes as the number M of BS antennas increases, and the selection diversity surprisingly turns to provide a slightly higher link capacity than the maximal-ratio diversity when M becomes fairly large, i.e., M=32.

In Fig. 3, the CDF of the link capacity achievable by the optimal JTRD is also plotted for comparison. The transmit and receive diversity weight vectors, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$, of optimal JTRD are the eigenvectors corresponding to the largest eigenvalues of $\mathbf{H}^{H}\mathbf{H}$ and $\mathbf{H}\mathbf{H}^{H}$, respectively [5, 15]. The link capacity achievable by the optimal JTRD can be computed similarly to suboptimal JTRD by replacing the received SNR with $\gamma=\Gamma\omega^{+}$, where ω^{+} is the maximum eigenvalue of $\mathbf{H}\mathbf{H}^{H}$ (also $\mathbf{H}^{H}\mathbf{H}$). It is interesting to note that when N=2, the link capacity gap between the user-driven suboptimal JTRD using selection diversity and the optimal JTRD is not that big (i.e., a fraction of bps/Hz) when M is as large as 32. When N=4, the link capacity gap becomes large, but it is still a fraction of bps/Hz when M is as large as 32. Remembering that the optimal JTRD requires solving the eigen-equation composed of the MIMO channel, the user-driven suboptimal JTRD using selection diversity is quite simple and practical.



(a) N=2



(b) N=4

Fig. 3 CDF of link capacity.

As a summary, the use of selection diversity at UE is not always disadvantageous. If BS has a fairly large number of antennas while UE has only a few antennas due to its space limitation and hardware complexity limitation, higher link capacity can be achieved by the use of selection diversity at UE. In beyond 5G systems, mmWave band will be extensively utilized and thus, BS can equip a large number of antennas. In such a situation, UE can utilize simple diversity scheme such as selection diversity. This is practically important advantage of user-driven suboptimal JTRD.

However, even though mmWave band is used, it may not be always possible for BS to equip a fairly large number (e.g. M>64) of diversity antennas while keeping all antennas experience close-to-independent fading. If the number of BS antennas is about 4 times larger than that of UE antennas, the user-driven suboptimal JTRD using selection diversity provides almost the same link capacity as using maximal-ratio diversity. Considering its lower hardware complexity and lower signal processing complexity, the user-driven suboptimal JTRD using selection diversity is advantageous.

V. Conclusions

In this paper, we investigated the user-driven suboptimal JTRD in an asymmetric MIMO fading channel. In a practical wireless system, the number of UE antennas may be only a few due to its space limitation and hardware complexity limitation although BS has a relatively sufficient space to equip a large number of antennas. Based on the derived closed-form expression for the received SNR in such an asymmetric MIMO channel, we have shown by Monte-Carlo numerical evaluation that, when the number of BS antennas is fairly large compared to that of UE, the user-driven suboptimal JTRD using selection diversity provides a slightly higher diversity gain than using maximal-ratio diversity and that the link capacity gap between the user-driven suboptimal JTRD and the optimal JTRD becomes small. This is quite an attractive result from a practical point of view since selection diversity requires lower hardware complexity as well as lower signal processing complexity than maximal-ratio diversity.

Recently, we proposed a recursive solution method for obtaining the optimal JTRD weight vectors instead of solving eigen-equations composed of the MIMO channel matrix [16]. The use of selection diversity weight as the UE's initial weight setting may lead to faster convergence to the optimal JTRD weight vectors than the use of maximal-ratio diversity. We will investigate this in our future study.

User-driven suboptimal JTRD (also user-driven optimal JTRD) has a unique feature that UE having any number of antennas can be viewed as a virtual single-antenna UE. Therefore, in a multiuser environment, all UEs each having a different number of antennas can be flexibly spatial-multiplexed. Multiuser JTRD in a not that strongly asymmetric MIMO fading channel was studied in [17]. How advantageous the user-driven suboptimal multiuser JTRD using selection diversity in a strongly asymmetric MIMO fading channel is compared to using maximal-ratio diversity is left as our future study.

Acknowledgment

A part of this work was conducted under "R&D for further advancement of the 5th generation mobile communication system" (JPJ000254) commissioned by the Ministry of Internal Affairs and Communications in Japan.

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