JOURNAL OF THE KOREA ELECTROMAGNETIC ENGINEERING SOCIETY, VOL. 6, NO. 4, DEC. 2006 JKEES 2006-6-4-05

Analysis on the Impact of Multiple-Antenna Transmit Schemes on Multiuser Diversity

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Abstract

In this paper, the performance of a multiuser diversity system combined with a multi-element transmit antenna system is analyzed under the assumption of independent Rayleigh fading. A measure of system level performance is an average channel capacity as a function of the number of users and antennas. Average channel capacity is obtained from the instantaneous signal-to-noise ratio(SNR) distribution combined by both transmit diversity(TD) at each link and multiuser diversity at system level. Numerical results show that closed-loop antenna techniques provide an additional gain with multiuser diversity system due to array gain, even though space diversity gain reduces multiuser diversity gain. On the other hand, the space-time block coding(STBC) that provides full order space diversity gain only has a destructive influence on multiuser diversity.

Key words : Spatial Diversity, Multiuser Diversity, Channel Capacity, Transmit Diversity.

Ⅰ. Introduction

Recently, increasing demands for wireless services are driving the demand to increase system capacity. Multi-element transmit antenna techniques and radio resource management by employing packet scheduling are the key techniques that increase system capacity in packet switched systems[1],[2]. Until now the interaction between packet scheduling and multi-element transmit antenna techniques has been studied in [3]~[6]. Most studies have analyzed the combined performance of transmit diversity and scheduling by using a system level simulation model[3]~[5] while only a study has assessed on the interactions between multiuser diversity and spatial diversity by using an analytical model[6]. However, [6] is confined to the analysis on the impact of space-time block coding(STBC) on multi-user diversity. A recent study presents a general asymptotic result that for any scheduling algorithm where transmit diversity techniques result in reduction of system throughput[7],[8].

In this paper, we analyze the impact of multi-element transmit antenna system on multiuser diversity under the assumption of independent Rayleigh fading by using an exact analytical model. A measure of system level performance is an average channel capacity as a function of the number of users and antennas. Spectral efficiency is obtained from the distribution of the instantaneous signal-to-noise ratio(SNR) both transmit diversity(TD) at each link and multiuser diversity at system level when the transmitter adapts to channel variations using a constant power variable rate strategy. We consider a system with the *fair-time* and *fair-access* algorithm each combined with STBC, switched transmit diversity(STD) and the transmit adaptive array(TxAA) scheme, respectively. The fair-time algorithm schedules users with same probability without consideration for users' channel state while fair-access scheduler decides to send a packet to a user with the largest instantaneous SNR to mean SNR ratio. Numerical results are presented to point out the effects of multi-element transmit antenna techniques on multiuser diversity system.

Ⅱ. Capacity Analysis of Fair Scheduling with Transmit Diversity

We consider the downlink of a single-cell wireless system with K number of mobile users in frequency flat Rayleigh block fading channel so that the channel coefficients are constant over packet duration. The transmitter adapts to channel variations using a constant power variable rate strategy. The transmission rate is subject to the feedback information measured as function of channel quality. We assume that there is negligible delay and error in the feedback channel.

We consider two fair scheduling algorithms. The first one is a fair-time scheduler such as a round robin scheduler that routes the transmission of packets equally across users without consideration for users' channel state. The second is a fair-access scheduler which selects a

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Manuscript received October 16, 2006 ; revised December 5, 2006. (ID No. 20061016-025J)

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user with the largest instantaneous SNR to average SNR ratio at each time slot. Assuming identical small-scale fading statistics across mobile users, the fair-access scheduler provides equal chance to all mobile users for packet transmission regardless of the average SNR of mobile users. The STBC, STD and TxAA schemes are considered in these multiuser packet data systems.

2-1 Transmit Diversity Techniques

Spatial diversity is introduced into the signal by transmission through an n_T number of multiple antennas. In addition to diversity gain that mitigates deep fades by combining independent Rayleigh fading from multiple transmit-antennas, array gain lifting the average received power can also be incorporated through channel state information(CSI) feedback. This leads to the categorization of TD methods into open-loop methods such as STBC providing diversity gain only and closed-loop methods that have both diversity gain and array gain. We consider STBC, STD and TxAA schemes that are representatives of open-loop and closed-loop TD techniques.

If we assume that the feedback mechanism in STD and TxAA perfectly track the channel conditions of the downlink and that ideal space-time block codes which achieve a rate of one and full diversity gain is used, the maximum achievable SNR γ_k^{TD} of the kth user is shown as[1]:

$$\gamma_k^{\mathrm{SISO}} = \bar{\gamma}_k |h_{1,k}|^2 = \bar{\gamma}_k \alpha_k^{\mathrm{SISO}} \tag{1}$$

$$\gamma_k^{\mathrm{STBC}} = \frac{\bar{\gamma}_k}{n_T} \sum_{i=1}^{n_T} |h_{i,k}|^2 = \bar{\gamma}_k \alpha_k^{\mathrm{STBC}} \tag{2}$$

$$\gamma_k^{\mathrm{STD}} = \bar{\gamma}_k \max_{i=1,\cdots,n_T} |h_{i,k}|^2 = \bar{\gamma}_k \alpha_k^{\mathrm{STD}}, \tag{3}$$

and

$$\gamma_k^{\mathrm{TxAA}} = \bar{\gamma}_k \sum_{i=1}^{n_T} |h_{i,k}|^2 = \bar{\gamma}_k \alpha_k^{\mathrm{TxAA}} \tag{4}$$

where SISO implies the single transmit antenna case. The variable $\bar{\gamma}_k$ denotes the average SNR of the kth user and $h_{i,k}$ represents the complex channel coefficient for the path traveled from the transmit antenna i to the receive antenna of the kth user. Channel coefficients are assumed to be independent zero-mean and unit variance complex Gaussian random variables. The expression α_k^{TD} denotes the instantaneous channel gain combined by the corresponding TD scheme for the k th user. The probability density functions(PDF) of α_k^{TD} are given by[9]

$$f_\alpha^{\mathrm{SISO}}(\gamma) = e^{-\gamma}, \gamma \geq 0, \tag{5}$$

$$f_\alpha^{\mathrm{STBC}}(\gamma) = \frac{n_T^{n_T}}{(n_T-1)!} \gamma^{n_T-1} e^{-n_T\gamma}, \gamma \geq 0, \tag{6}$$

$$f_\alpha^{\mathrm{STD}}(\gamma) = n_T e^{-\gamma}(1-e^{-\gamma})^{n_T-1}, \gamma \geq 0, \tag{7}$$

and

$$f_\alpha^{\mathrm{TxAA}}(\gamma) = \frac{1}{(n_T-1)!} \gamma^{n_T-1} e^{-\gamma}, \gamma \geq 0. \tag{8}$$

2-2 Fair Scheduling with Transmit Diversity

A fair scheduling scheme has a common feature in that the user to be serviced is selected regardless of the average SNR, i.e, locations of candidates to ensure resource fairness. In this paper, we consider two fair scheduling algorithms. The first one is a fair-time scheduler that allocates equal access time to all the mobile users without consideration for users' channel state. Thus, the fair-time scheduling algorithm has no multiuser diversity gain. The second is a fair-access scheduler which selects a user with the largest instantaneous SNR to average SNR ratio at each time slot. On the assumption of identical small-scale fading statistics across mobile users, the fair-access scheduler also provides equal access time to all mobile users in like manner of the fair-time scheduler but provides multiuser diversity gain by transmitting to users with stronger channels at all times.

Since both the fair-time and the fair-access scheduler have no consideration of the average SNR of candidates for packet scheduling, the combined instantaneous SNR of the selected mobile users at each time slot by a fair scheduler, $\tilde{\gamma}_{\mathrm{FS}}^{\mathrm{TD}}$ can be expressed as a multiplication process of two independent random variables of the combined average SNR of the scheduled users, $\tilde{\bar{\gamma}}$ and the combined instantaneous channel gain of the scheduled users, $\tilde{\alpha}_{\mathrm{FS}}^{\mathrm{TD}}$ as follows

$$\tilde{\gamma}_{\mathrm{FS}}^{\mathrm{TD}} = \tilde{\bar{\gamma}} \cdot \tilde{\alpha}_{\mathrm{FS}}^{\mathrm{TD}}. \tag{9}$$

Note that $\tilde{\alpha}_{\mathrm{FS}}^{\mathrm{TD}}$ is variable according to both TD and scheduling schemes used. On the other hand, $\tilde{\bar{\gamma}}$ is constant with TD and fair scheduling schemes used because both schemes affect only small-scale fading statistics of scheduled users. Furthermore, on the assumption of identical small-scale fading statistics across candidates, the combined average SNR of the scheduled users, $\tilde{\bar{\gamma}}$ shows identical statistics with the average SNR of the candidates, $\bar{\gamma}$ because all candidates have equal access time. Let us assume the distribution of $\bar{\gamma}$ is given by

$$f_{\bar{\gamma}}(\gamma) = \frac{1}{K} \sum_{k=1}^{K} \delta(\gamma - \bar{\gamma}_k). \tag{10}$$

The PDF of $\tilde{\gamma}_{\mathrm{FS}}^{\mathrm{TD}}$ is given by

$$\begin{aligned} f_{\tilde{\gamma}_{\mathrm{FS}}^{\mathrm{TD}}}(\gamma) &= \int_{-\infty}^{\infty} \frac{1}{|x|} f_{\bar{\gamma}}(x) f_{\tilde{\alpha}_{\mathrm{FS}}^{\mathrm{TD}}}\left(\frac{\gamma}{x}\right) dx \\ &= \frac{1}{K}\sum_{k=1}^{K} \frac{1}{\gamma_k} f_{\tilde{\alpha}_{\mathrm{FS}}^{\mathrm{TD}}}\left(\frac{\gamma}{\gamma_k}\right). \end{aligned} \tag{11}$$

The average channel capacity is given by[10]

$$C_{\mathrm{FS}}^{\mathrm{TD}} = \int_0^{\infty} \log_2(1+\gamma) f_{\tilde{\gamma}_{\mathrm{FS}}^{\mathrm{TD}}}(\gamma) d\gamma \tag{12}$$

when the transmitter adapts to the channel variations using a constant power variable rate strategy.

Fair-time Scheduler

We consider the fair-time scheduler in which users are allocated time slot with same probability. Thus, the PDF of the combined instantaneous channel gain of the selected users at each time slot by the fair-time scheduler, $\tilde{\alpha}_{\mathrm{FT}}^{\mathrm{TD}}$ is same as the PDF of the instantaneous channel gain combined by TD system at each link, α_k^{TD} as follows

$$f_{\tilde{\alpha}_{\mathrm{FT}}^{\mathrm{TD}}}(\gamma) = f_{\alpha^{\mathrm{TD}}}(\gamma) \tag{13}$$

where the index k of α_k^{TD} is omitted by the assumption of identical fading statistics for all mobile users that results in identical distribution of instantaneous channel gain combined by TD for all users. The PDFs of combined instantaneous SNR distribution by the fair-time scheduler become

$$f_{\tilde{\gamma}_{\mathrm{FT}}^{\mathrm{SISO}}}(\gamma) = \frac{1}{K}\sum_{k=1}^{K} \frac{1}{\bar{\gamma}_k} e^{-\gamma/\bar{\gamma}_k}, \tag{14}$$

$$f_{\tilde{\gamma}_{\mathrm{FT}}^{\mathrm{STBC}}}(\gamma) = \frac{{n_T}^{n_T} \cdot \gamma^{n_T-1}}{K \cdot (n_T-1)!} \sum_{k=1}^{K} \frac{1}{{\bar{\gamma}_k}^{n_T}} e^{-\gamma \cdot n_T/\bar{\gamma}_k}, \tag{15}$$

$$f_{\tilde{\gamma}_{\mathrm{FT}}^{\mathrm{STD}}}(\gamma) = \frac{1}{K}\sum_{k=1}^{K} \frac{n_T}{\bar{\gamma}_k} e^{-\gamma/\bar{\gamma}_k}(1-e^{-\gamma/\bar{\gamma}_k})^{n_T-1}, \tag{16}$$

and

$$f_{\tilde{\gamma}_{\mathrm{FT}}^{\mathrm{TxAA}}}(\gamma) = \frac{1}{K}\sum_{k=1}^{K} \frac{\gamma^{n_T-1}}{(n_T-1)! \cdot {\bar{\gamma}_k}^{n_T}} e^{-\gamma/\bar{\gamma}_k}. \tag{17}$$

The final expressions of the average capacity by the corresponding TD schemes are obtained by (12)

$$\begin{aligned} C_{\mathrm{FT}}^{\mathrm{SISO}} &= \int_0^{\infty} \log_2(1+\gamma) f_{\gamma}(\gamma) d\gamma \\ &= \sum_{k=1}^{K} \frac{1}{K \cdot \bar{\gamma}_k} \int_0^{\infty} \log_2(1+\gamma) e^{-\gamma/\bar{\gamma}_k} d\gamma, \end{aligned} \tag{18}$$

$$\begin{aligned} C_{\mathrm{FT}}^{\mathrm{STBC}} &= \sum_{k=1}^{K} \frac{1}{K \cdot (n_T-1)!} \left(\frac{n_T}{\bar{\gamma}_k}\right)^{n_T} \\ &\quad \cdot \int_0^{\infty} \log_2(1+\gamma) \gamma^{n_T-1} e^{-\gamma \cdot n_T/\bar{\gamma}_k} d\gamma, \end{aligned} \tag{19}$$

$$\begin{aligned} C_{\mathrm{FT}}^{\mathrm{STD}} &= \sum_{k=1}^{K} \frac{n_T}{K \cdot \bar{\gamma}_k} \int_0^{\infty} \log_2(1+\gamma) \\ &\quad \cdot e^{-\gamma/\bar{\gamma}_k}(1-e^{-\gamma/\bar{\gamma}_k})^{n_T-1} d\gamma, \end{aligned} \tag{20}$$

and

$$\begin{aligned} C_{\mathrm{FT}}^{\mathrm{TxAA}} &= \sum_{k=1}^{K} \frac{1}{K \cdot (n_T-1)! \cdot {\bar{\gamma}_k}^{n_T}} \\ &\quad \cdot \int_0^{\infty} \log_2(1+\gamma) \gamma^{n_T-1} e^{-\gamma/\bar{\gamma}_k} d\gamma. \end{aligned} \tag{21}$$

Fair-access Scheduler

The fair-access scheduler decides to send a packet to the user k^* with the largest instantaneous SNR to mean SNR ratio at each time slot. Hence, multiuser diversity gain is obtained by scheduling the transmission to the user having the relatively better channel condition. And in terms of transmission time a certain degree of fairness is achieved among users. The scheduling algorithm is expressed as

$$k^* = \arg \max_{k \in \{1,2,\ldots,K\}} \frac{\gamma_k^{\mathrm{TD}}}{\bar{\gamma}_k}. \tag{22}$$

Therefore, the final decision variables for fair-access scheduling become the instantaneous channel gain of candidates, $\alpha_k^{\mathrm{TD}}, k=1,\cdots,K$ since $\alpha_k^{\mathrm{TD}} = \gamma_k^{\mathrm{TD}}/\bar{\gamma}_k$.

The PDF of the instantaneous channel gain combined by the fair-access scheduler, $\tilde{\alpha}_{\mathrm{FT}}^{\mathrm{TD}}$ can be computed using order statistics[11] on the assumption of identical distribution of all α_k^{TD}

$$f_{\tilde{\alpha}_{\mathrm{FA}}^{\mathrm{TD}}}(\gamma) = K f_{\alpha^{\mathrm{TD}}}(\gamma)(F_{\alpha^{\mathrm{TD}}}(\gamma))^{K-1} \tag{23}$$

where $F_{\alpha^{\mathrm{TD}}}(\gamma)$ denotes the cumulative distribution function(CDF) of α_k^{TD} and the index k of α_k^{TD} is omitted by the assumption of identical fading statistics for all mobile users. Thus, by (11) and (23) the PDFs of instantaneous SNR distribution combined by the fair-access scheduler can be written as

$$f_{\tilde{\gamma}_{\mathrm{FA}}^{\mathrm{SISO}}}(\gamma) = \sum_{k=1}^{K} \frac{1}{\bar{\gamma}_k} e^{-\gamma/\bar{\gamma}_k}(1-e^{-\gamma/\bar{\gamma}_k})^{K-1}, \tag{24}$$

$$\begin{aligned} f_{\tilde{\gamma}_{\mathrm{FA}}^{\mathrm{STBC}}}(\gamma) &= \sum_{k=1}^{K} \frac{n_T^{n_T}}{\bar{\gamma}_k \cdot (n_T-1)!} \left(\frac{\gamma}{\bar{\gamma}_k}\right)^{n_T-1} e^{-n_T\gamma/\bar{\gamma}_k} \\ &\quad \cdot \left(1 - e^{-n_T\gamma/\bar{\gamma}_k} \sum_{m=0}^{n_T-1} \frac{(n_T\gamma/\bar{\gamma}_k)^m}{m!}\right)^{K-1}, \end{aligned} \tag{25}$$

$$f_{\tilde{\gamma}_{\mathrm{FA}}^{\mathrm{STD}}}(\gamma) = \sum_{k=1}^{K} \frac{n_T}{\bar{\gamma}_k} e^{-\gamma/\bar{\gamma}_k}(1-e^{-\gamma/\bar{\gamma}_k})^{Kn_T-1} \tag{26}$$

and

$$f_{\tilde{\gamma}_{\mathrm{FA}}^{\mathrm{TxAA}}}(\gamma) = \sum_{k=1}^{K} \frac{\gamma^{n_T-1}}{(n_T-1)! \cdot \overline{\gamma}_k{}^{n_T}} e^{-\gamma/\overline{\gamma}_k} \cdot \left(1 - e^{-\gamma/\overline{\gamma}_k} \sum_{m=0}^{n_T-1} \frac{(\gamma/\overline{\gamma}_k)^m}{m!}\right)^{K-1}. \tag{27}$$

The final expressions for the average capacity by the corresponding TD schemes are expressed as

$$C_{\mathrm{FA}}^{\mathrm{SISO}} = \sum_{k=1}^{K} \frac{1}{\overline{\gamma}_k} \int_0^{\infty} \log_2(1+\gamma) \cdot e^{-\gamma/\overline{\gamma}_k} (1 - e^{-\gamma/\overline{\gamma}_k})^{K-1} d\gamma, \tag{28}$$

$$C_{\mathrm{FA}}^{\mathrm{STBC}} = \sum_{k=1}^{K} \frac{n_T^{n_T}}{\overline{\gamma}_k{}^{n_T}(n_T-1)!} \cdot \int_0^{\infty} \log_2(1+\gamma) e^{-\frac{n_T\gamma}{\overline{\gamma}_k}} \gamma^{n_T-1} \cdot \left(1 - e^{-\frac{n_T\gamma}{\overline{\gamma}_k}} \sum_{m=0}^{n_T-1} \frac{(n_T\gamma/\overline{\gamma}_k)^m}{m!}\right)^{K-1} d\gamma, \tag{29}$$

$$C_{\mathrm{FA}}^{\mathrm{STD}} = \sum_{k=1}^{K} \frac{n_T}{\overline{\gamma}_k} \int_0^{\infty} \log_2(1+\gamma) \cdot e^{-\frac{\gamma}{\overline{\gamma}_k}} \left(1 - e^{-\frac{\gamma}{\overline{\gamma}_k}}\right)^{Kn_T-1} d\gamma, \tag{30}$$

and

$$C_{\mathrm{FA}}^{\mathrm{TxAA}} = \sum_{k=1}^{K} \frac{1}{\overline{\gamma}_k{}^{n_T}(n_T-1)!} \cdot \int_0^{\infty} \log_2(1+\gamma) \gamma^{n_T-1} e^{-\frac{\gamma}{\overline{\gamma}_k}} \cdot \left(1 - e^{-\frac{\gamma}{\overline{\gamma}_k}} \sum_{m=0}^{n_T-1} \frac{(\gamma/\overline{\gamma}_k)^m}{m!}\right)^{K-1} d\gamma. \tag{31}$$

Ⅲ. Numerical Results and Discussion

In this section an average channel capacity of fair scheduling algorithms for each transmit-diversity scheme is presented. To perform multiuser performance analysis we assume that $\overline{\gamma}_k$ is uniformly distributed in linear scale and $\overline{\gamma}_k$ can be extracted from (32):

$$\overline{\gamma}_k = \overline{g} + k\sigma\sqrt{\frac{3}{n(n+1)}}, \quad k = 0, \pm 1, \cdots, \pm n \tag{32}$$

where $\overline{g}$ and σ respectively denote the mean and standard deviation of $\overline{\gamma}_k$ and $n = \frac{K-1}{2}$. The number of users per sector K is always assumed to be an odd number for symmetric distribution of $\overline{\gamma}_k$. For our analysis, $\overline{g}$ and σ are assumed to be 4.0 and 2.0, respectively.

Fig. 1 shows the comparison of CDF's between the simulation and our analysis results of the instantaneous SNR combined by the fair-access scheduler when a SISO, STBC, STD and TxAA are considered. The simulated data of 100,000 samples of the fading channel with the average SNR $\overline{\gamma}_k$ taken from (32) are used. For different values of K and TD schemes, the analysis curves exactly match simulation curves, which verifies our analytic approach.

Fig. 2 shows results of average channel capacity per sector versus the average SNR for the different TD schemes when using the fair-time scheduler. We assume two extreme fading environments, fully correlated channels and uncorrelated channels. Since the fair-time scheduling algorithm provides no multiuser diversity

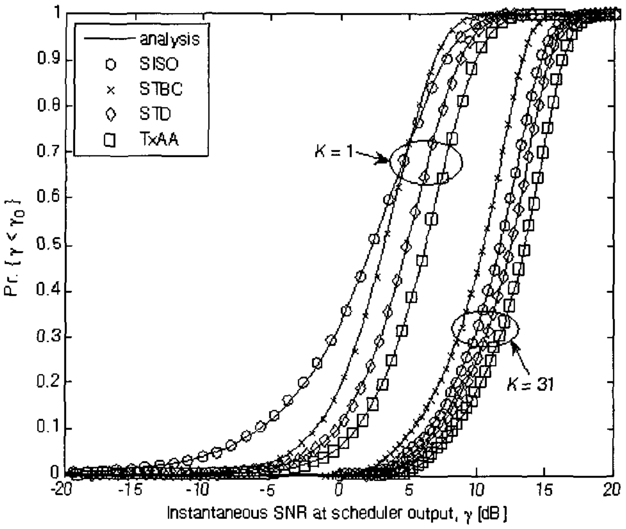

Fig. 1. Comparison of cumulative density function between the simulation and analysis(n_T=2).

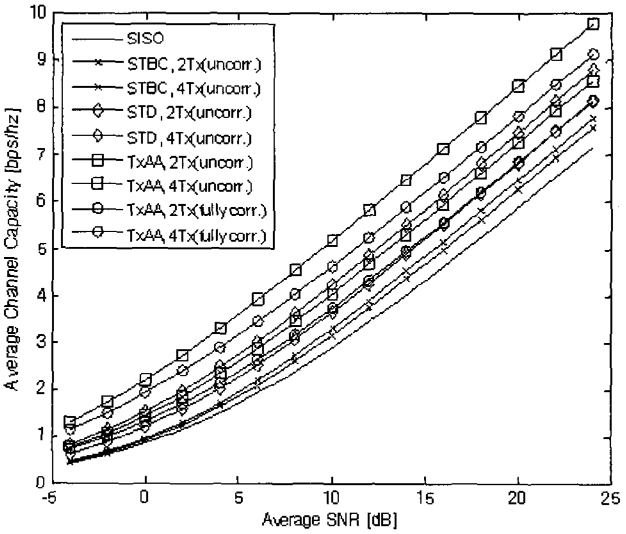

Fig. 2. Average channel capacity of the fair-time scheduler.

gain, the system level spectral efficiency of the fair-time scheduler shown in Fig. 2 is identical with that of link level. Thus, the system level spectral efficiency reflects space diversity gain, array gain, or both according to fading environments. The STBC shows increasing diversity gain with space diversity order in uncorrelated channels. The TxAA presents only array gain in fully correlated channel or both in uncorrelated channel. The capacity difference of TxAA between two channels indicates the spectral efficiency achieved by space diversity gain.

Fig. 3 shows plots of average channel capacity per sector as a function of the average SNR for the fair-access scheduler where K=31. The capacity results of STBC in uncorrelated channels show that a larger number of transmit antennas increases space diversity gain at each link but decreases the system capacity, indicating that space diversity without array gain has a bad effect on multiuser diversity. TD is used to reduce the fading fluctuations but the multiuser diversity exploits the fact that different users in a system have vastly different SNR.

On the other hand, the capacity results of STD and TxAA in uncorrelated channels show that a larger number of transmit antennas increases the system capacity in spite of increased space diversity gain at each link, indicating that array gain of TxAA and STD improves the system capacity even though space diversity gain reduces multiuser diversity gain. Furthermore, the capacity of TxAA improves in fully correlated channel and is always better than that of the other cases. This is due to array gain that increases an average SNR at each link in proportion to the number of transmit antennas without effect on multiuser diversity. It can be seen that TxAA provides $10\log_{10}n_T$ dB gain over single antenna transmission in fully correlated channel in both Fig. 2 and Fig. 3.

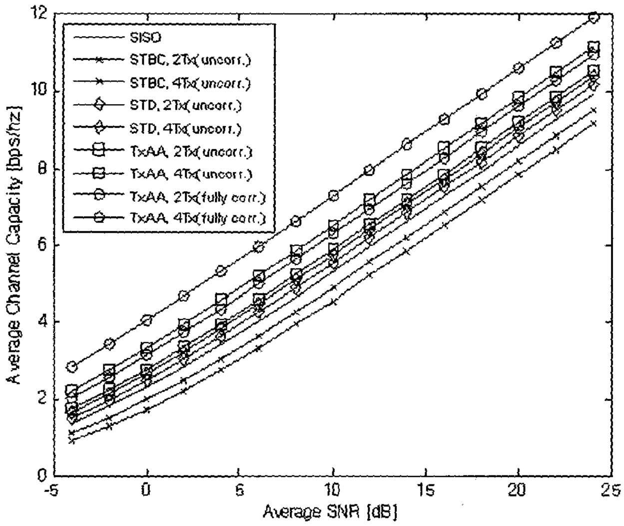

Fig. 3. Average channel capacity of the fair-access scheduler(K=31).

Fig. 4 and Fig. 5 show the multiuser diversity gain as a function of average SNR and K, respectively. In both figures, let us define multiuser diversity gain G as the capacity difference between the fair-access and the fair-time scheduler, as

$$G = C_{\mathrm{FA}}^{\mathrm{TD}} - C_{\mathrm{FT}}^{\mathrm{TD}}. \tag{33}$$

Both figures show that multiuser diversity gain increases with SNR and K but decreases as the number of antennas increases. A larger number of users increases the order of multiuser diversity and hence multiuser diversity gain improves. On the other hand, a larger number of transmit antennas increases space diversity

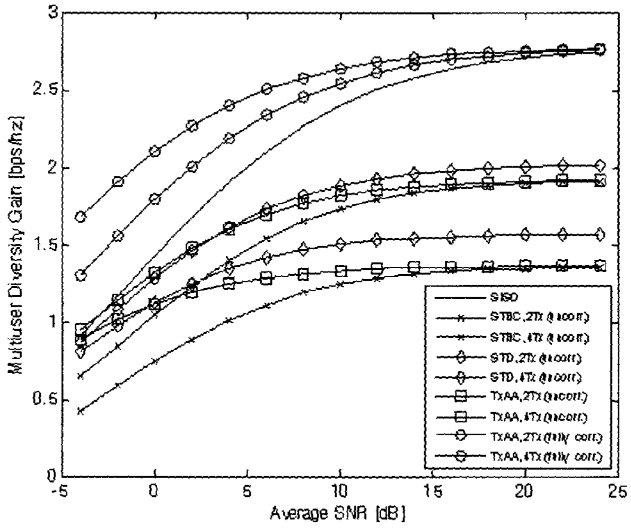

Fig. 4. Multiuser diversity gain versus average SNR(K=31).

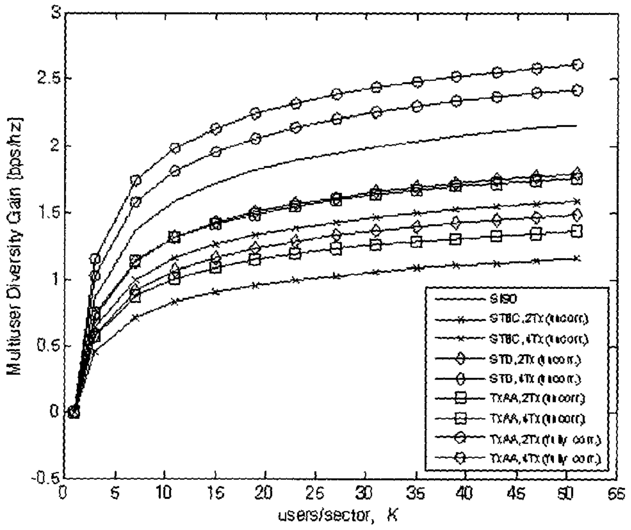

Fig. 5. Multiuser diversity gain versus K.

order and gain at each link, which reduces multiuser diversity gain.

In Fig. 4 we can see that the TxAA and STBC with the same space diversity order provide about the same multiuser diversity gain at high SNR, which results from the fact that array gain of TxAA contributes the same increase in $C_{\mathrm{FT}}^{\mathrm{TxAA}}$ and $C_{\mathrm{FT}}^{\mathrm{TxAA}}$. This implies that array gain has no influence on multiuser diversity gain and just lifts up the average SNR as a whole.

The TxAA and STD each combined with the fair-access scheduling offer a significant gain over no TD because TxAA and STD provide array gain by closed-loop method together with diversity gain. On the other hand, the STBC that provides only full order diversity gain is shown to offer inferior performance to no TD under multiuser diversity system. Diversity gain not only reduces the severity of destructive fades but also the probability of encountering very high constructive fading peaks, which has destructive influence on multiuser diversity. This result agrees well with the results of system level simulation in [5] and [6]. These characteristics can be found more definitely when increasing transmit antenna elements.

Ⅳ. Conclusion

In this paper, we have derived expressions for the average channel capacity of TxAA, STD and STBC each combined with a fair-time and a fair-access scheduling algorithm to find out the impact of transmit diversity on the performance of multiuser diversity. Numerical results show that the closed-loop antenna techniques with array gain such as TxAA and STD provide an additional gain with multiuser diversity, even though space diversity reduces multiuser diversity gain. On the other hand, the open-loop transmit method such as STBC that provides full order diversity gain only shows destructive influence on multiuser diversity.

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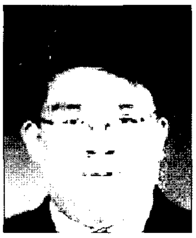

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