Abstract—In this paper, we present a novel Mutual Information (MI) based spatial frequency domain packet scheduling for downlink Orthogonal Frequency Division Multiple Access (OFDMA) multiuser MIMO systems. The proposed scheduler is designed to exploit the available multiuser diversity in time, frequency and spatial domains. The analysis model is based on the generalized 3GPP LTE downlink transmission for which two Spatial Division Multiplexing (SDM) multiuser MIMO schemes are investigated: Single User (SU) and Multi-user (MU) MIMO schemes. The results show that the proposed MU-MIMO scheduler is a more realistic solution and provides fairness among users for the system under consideration.

I. INTRODUCTION

In 3GPP Long Term Evolution (LTE) (also known as Evolved-UMTS Terrestrial Radio Access (E-UTRA)), Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiple Access (OFDMA) have been selected for downlink transmission [1]. Both Spatial Division Multiplexing (SDM) and Frequency Domain Packet Scheduling (FDPS) have been proposed. SDM simply divides the data stream into multiple independent sub-streams, which are subsequently transmitted by different antennas simultaneously. It is used to improve the spectral efficiency of the system. FDPS allows the packet scheduler at the Base Station (BS) to exploit the available multiuser diversity in both time and frequency domain. In [2], it is shown that the MIMO schemes with combined SDM and FDPS can further enhance the system performance.

This paper investigates system performance of the multiuser SDM MIMO schemes with FDPS for downlink transmission. The studied model is based on the generalized 3GPP LTE MIMO-OFDMA based downlink transmission model with some idealized assumptions in order to facilitate performance analysis. We call our studied system the “LTE type” system to differentiate it from the real LTE system. Both open loop and closed loop transmission are considered as possible solutions in 3GPP LTE. However, the closed loop solution provides both diversity and array gains, and hence a superior performance. Open loop and closed loop MIMO corresponds to the MIMO systems without and with channel state information at the transmitter, respectively [1]. Due to its simplicity and robust performance, the use of linear precoding has been widely studied as a closed loop scheme [2, 3]. In this paper, we refer to the open loop MIMO as the SDM MIMO without precoding, and the closed loop MIMO as the linearly precoded SDM MIMO.

II. SYSTEM MODEL

In this section, we describe the system model of multiuser SDM MIMO schemes for 3GPP LTE downlink transmission with packet scheduling. The basic scheduling unit in LTE is the Physical Resource Block (PRB), which consists of a number of consecutive OFDM sub-carriers reserved during the transmission of a fixed number of OFDM symbols. One PRB of 12 contiguous subcarriers can be configured for localized transmission in a sub-frame. In the localized FDMA transmission scheme, each user’s data is transmitted by consecutive subcarriers, while for the distributed FDMA transmission scheme, the user’s data is transmitted by distributed subcarriers [1]. Two
SDM schemes are now under investigation for the localized transmission scheme [1]: Single User (SU) MIMO and Multi-User (MU) MIMO schemes. They differ in terms of the freedom allowed to the scheduler in the spatial domain [1]. With SU-MIMO scheme, only one single user can be scheduled per PRB; whereas with MU-MIMO scheme, multiple users can be scheduled per PRB, one user for each sub-stream.

The system considered here has $n_t$ transmit antennas at the Base Station (BS) and $n_r$ receive antennas at the $i$th Mobile Station (MS), $i = 1, 2, \cdots, K_T$, where $K_T$ is the total number of users in the system. The number of users simultaneously served on each PRB for the MU-MIMO scheme is usually limited by the number of transmit antennas $n_t$. The scheduler in BS selects $K$ users per PRB from the $K_T$ active users in the cell for data transmission. Denote by $\zeta_i$ the set of users scheduled on the $i$th PRB, $K = |\zeta_i|$ and $n_r = \sum_{i \in \zeta_i} n_r$, where $n_r$ is the total number of receive antennas for all the scheduled users. We assume that the $i$th user transmits $l_i$ parallel data streams when it is scheduled, and we denote the total number of data streams of all $K$ users by $L = \sum_{i=1}^{K} l_i$.

There are $L$ data streams for each PRB, each data stream contains $N$ data symbols. These data streams are first passed through a precoding matrix $B$, which will be further explained later. The outputs, together with the outputs from other PRBs, are then mapped to $M$ ($M >> N$) orthogonal subcarriers followed by a $M$ point Inverse Fast Fourier Transform (IFFT) to convert them to a frequency domain complex signal sequence. A Cyclic Prefix (CP) is inserted into the sequence before it is passed to the Radio Frequency (RF) module. The length of CP is chosen to be longer than the channel delay spread to remove Inter-Symbol Interference (ISI) and Inter-Channel Interference (ICI). On the receiver side, the opposite operating procedure is performed after the noisy signals are received at the receiver antennas. A MIMO Frequency Domain Equalizer (FDE) is applied to the frequency domain signals after subcarrier demapping. For simplicity, we employ a linear Minimum Mean Squared Error (MMSE) equalizer, which provides a good tradeoff between the noise enhancement and the multiple stream interference mitigation [8].

With a linear MMSE equalizer, the signal at the detector of the $k$th MS, $k \in \zeta_i$, at the $n$th subcarrier of the PRB is given by

$$y_{k,n} = A_{k,n} \left( R_{k,n} x_{k,n} + w_{k,n} \right),$$

where $R_{k,n}$ is an $n_r^k \times n_t$ complex channel matrix, each element of which represents the complex gain between each pair of transmit-receive antennas. $B_{k,n} \in \mathbb{C}^{n_r^k \times L}$ is the transmit precoding matrix for the $n$th subcarrier. $w_{k,n} \in \mathbb{C}^{n_r^k \times 1}$ is a circularly symmetric complex Gaussian noise vector with zero mean and covariance matrix $N_0 I \in \mathbb{R}^{n_r^k \times n_r^k}$. $x_{k,n} \in \mathbb{C}^{L \times 1}$ is the transmitted signal vector at the $n$th subcarrier, and $x_{k,n} = [x_{k,n}^T, \cdots, x_{k,n}^T, \cdots, x_{k,n}^T]^T$, where $x_{k,n} \in \mathbb{C}^{L \times 1}$ is the transmitted data symbols for the $k$th MS, $k \in \zeta_i$.

Let $B_n = [B_{1,n} \ B_{2,n} \cdots B_{K,n}]$, where $B_{i,n}$ is of size $n_t \times l_i$, then Eq. (1) becomes

$$y_{k,n} = A_{k,n} \left( H_{k,n} \sum_{i \in \zeta_n} B_{i,n} x_{i,n} + H_{k,n} B_{k,n} x_{k,n} + w_{k,n} \right).$$

The equalization matrix $A_{k,n} \in \mathbb{C}^{L \times n_r^k}$ can be derived under the MMSE criterion (such that $E[\| x_{k,n} - y_{k,n} \|^2]$ is minimized) as

$$A_{k,n} = B_{k,n}^H H_{k,n}^{-1} \left( H_{k,n} B_{k,n} x_{k,n} + w_{k,n} \right),$$

where $R_{k,n} = E[x_{k,n} x_{k,n}^H]$ and $R_{W,n} = E[w_{k,n} w_{k,n}^H] = N_0 I$. Eq. (3) holds since $E[x_{k,n} x_{k,n}^H] = 0$, $\forall j \neq k$.

Substituting (3) into (1) and with some simple matrix manipulations, we get

$$y_{k,n} = \left( \left[ \left[ R_{W,n} x_{k,n} + H_{k,n} B_{k,n} H_{k,n}^{-1} \right] \right] \right)^{H} \left( \left[ H_{k,n} B_{k,n} x_{k,n} + w_{k,n} \right] \right).$$

Forcing $H_{k,n} B_{j,n} = 0$, $\forall j \neq k$, $j, k \in \{1, \cdots, K\}$, $y_{k,n}$ can be expressed as

$$y_{k,n} = \left( \left[ \left[ R_{W,n} x_{k,n} + H_{k,n} B_{k,n} H_{k,n}^{-1} \right] \right] \right)^{H} \left( \left[ H_{k,n} B_{k,n} x_{k,n} + w_{k,n} \right] \right).$$

The second equality of (5) follows from the fact that $(A - BD^{-1}C)^{-1}BD^{-1} = A^{-1}B(D - CA^{-1}B)^{-1}$. Denoting by $\Phi_{k,n} = R_{W,n}^{-1/2} H_{k,n}$ and define $\Psi_{k,n} = \left[ \Psi_{k,n} \cdots \Psi_{k,n} \Psi_{k,n} \cdots \Psi_{k,n} \right]^T$. Using the Single Value Decomposition (SVD) to decompose $\Psi_{k,n}$, we have

$$\Psi_{k,n} = \left[ \tilde{U}_{k,n}^{(1)} \tilde{U}_{k,n}^{(0)} \right] \left[ \Sigma_{k,n} \right] \left[ \tilde{V}_{k,n}^{(1)} \tilde{V}_{k,n}^{(0)} \right]^H,$$

where $\tilde{V}_{k,n}$ contains the $n_t = \sum_{i \in \zeta} n_t^i$ columns of the right singular vectors of null space $\Psi_{k,n}$, which forms an orthogonal basis of $\Psi_{k,n}$. In the following, we let $m_{k,n} = n_t - \sum_{i \in \zeta} n_t^i$, then $\tilde{V}_{k,n}$ has dimension of $nt \times m_{k,n}$.

To eliminate the multi-user interference, we design the precoding matrix $B_k$ such that $\Phi_{k,n} B_{k,n} = 0$, $\forall j \neq k$, $j \in \{1, \cdots, K\}$. Let $\Psi_{k,n} = \Phi_{k,n} \tilde{V}_{k,n}$. With SVD, we have

$$\Psi_{k,n} = U_{k,n} A_{k,n} V_{k,n},$$

where $U_{k,n}$ and $V_{k,n}$ are unitary matrices, and the columns of $U_{k,n}$ and $V_{k,n}$ are the eigenvectors of $\Psi_{k,n}$ and $\Phi_{k,n}$, respectively. The singular values $\lambda_{k,n}^i$, $i \in \{1, 2, \cdots, K\}$, of $\Psi_{k,n}$ are the diagonal entries of $A_{k,n}$ and are arranged in the descending order. Now let $B_n = V_{k,n}^H \tilde{V}_{k,n}$, where $V_{k,n}$ is the right singular vector of $\Psi_{k,n}$, the channel can be decomposed into a parallel channel for different users. Thus, multi-user interference can be completely removed, i.e.,

$$y_{k,n} = \left( \left[ 1 + A_{k,n} A_{k,n} \right]^{-1} A_{k,n} U_{k,n} \tilde{F}_{k,n} w_{k,n} \right).$$
Consequently, the $i^{th}$ symbol $y_{k,n}(i), i \in \{1, \cdots, l_k\}$, can be expressed as

$$
y_{k,n}(i) = \frac{\lambda_j \psi_k^{i,j}}{1 + \lambda_j \psi_k^{i,j}} x_{k,n}(i) + \frac{\sqrt{\psi_k^{i,j}/N_0}}{1 + \lambda_j \psi_k^{i,j}} w_{k,n}(i),$$

where $w_{k,n}(i)$ is the $i^{th}$ element of the vector $U_k^H w_{k,n}$. From the above derivations, we can see that with the proposed precoding matrix and with the designed MMSE equalizer, the MIMO channel can be decomposed into many parallel channels. The interference among the antennas and the interference among the users can be completely removed.

Above we assume the transmitter can have perfect channel state information. In practice, this is an unrealistic assumption. Modern wireless communication standards, such as IEEE 802.16m (WiMAX), 3GPP Long Term Evolution (LTE), 3GPP LTE-Advanced, adopt the codebook based precoding scheme with limited channel state information (CSI) for MIMO scenarios. In such cases, NodeB and UEs have some predefined common codebooks and each element of the codebook can be indexed by Precoding Matrix Index (PMI). If scheduled for transmission, the user will be precoded using the corresponding precoding matrix. Together with channel quality indication (CQI), the selected PMI is fed back to assist NodeB’s scheduling, resource allocation and rate adaptation decisions for both open-loop and closed-loop Multi-user (MU)-MIMO.

The system needs to prepare a total of $Q = 2^T$ precoding matrices for a $T$-bits feedback channel. Based on the current channel realization, the receiver will decide which precoding matrix from the codebook is the most favorable and inform the transmitter to switch to that precoding matrix by feeding back its $T$-bit PMI. The codebook consists of a finite number of matrices, which represent a set of subspaces in the Grassmann manifold. Designing sets of $Q$ matrices that maximize the minimum subspace distance is known as Grassmannian subspace packing [11]. In this work we consider the use of the non-coherent constellation designs introduced in [12]. It has been shown to yield codebooks with large minimum distances and can be easily modified to work with any distance function on the Grassmann manifold.

III. Spatial Frequency Multiuser Scheduling

A. SINR expression and the mutual information for linearly precoded SDM MIMO schemes

In this section, we derive the SINR expression and the Mutual Information (MI) for the linearly precoded OFDMA MIMO system. The system model is described in Section II. The received signal at the $k^{th}$ MS, $k \in \mathcal{K}$, for the $n^{th}$ subcarrier after the linear MMSE equalizer is given by (1) for the MU-MIMO scheme. The received SINR for the $j^{th}$ spatial sub-stream can be obtained from Eq. (8)

$$
\gamma_j = \lambda_j^2 \rho_j = \lambda_j \rho_j, \quad j \in \{1, 2, \cdots, \min(n_k, m_k)\}
$$

where $\lambda_j$ is the $j^{th}$ largest non-zero eigenvalue of the matrix $\mathbf{Y}_k \mathbf{Y}_k^H$, $\mathbf{Y}_k = \mathbf{H}_k \mathbf{V}_k^{(0)} \in \mathbb{C}^{n_k \times m_k}$ and $\rho_j$ is the power allocated to the $j^{th}$ established sub-stream of the $k^{th}$ MS and $\rho_j = p_j/N_0$, where $N_0$ is the noise variance.

Based on Gaussian signaling and Shannon’s capacity theorem, the maximum achievable spectrum efficiency in bits/second/Hz for the $k^{th}$ user can be expressed as

$$r_k = \sum_j \log_2 (1 + \gamma_j),$$

where $\gamma_j$ is the received SINR for the $j^{th}$ substream of the $k^{th}$ user, and it is given by (9).

For broadband wireless communication systems, e.g., 3GPP LTE downlink, the total bandwidth $W$ is usually divided into a number of $M$ subcarriers. Among $M$ subcarriers, $N$ subcarriers ($N < M$) are allocated for data transmission. $K$ contiguous subcarriers form a scheduling RB. Let $I_{sub,1}$ and $|I_{sub,1}|$ be the index set of subcarriers assigned to user $i$ and the length of the set $I_{sub,1}$, respectively. Denote by $P_i^d$ the total transmitted power of user $i$. Assuming that the power is equally allocated over $I_{sub,1}$, then $p_{n,i} = P_i^d/|I_{sub,1}|$. The maximum achievable rate in bits per second for the $k^{th}$ user can then be written as

$$C_k = \sum_j \frac{W |I_{sub,k}|}{M} \log_2 (1 + \gamma_j).$$

So far, we have discussed the maximum achievable rate by assuming Gaussian signaling for the channel input. In real LTE systems, discrete time finite size signal constellations, e.g., M-QAM, are employed. The maximum achievable rate approach based on Gaussian signaling, e.g., (10) and (11), are therefore likely to be too optimistic for estimating the achievable rate in real systems. In this work, we consider the mutual information between the discrete channel input $\mathbf{u}$ and the channel output $\mathbf{v}$. For a MIMO channel $\mathbf{A}$ with $n_r$ transmit antennas and $n_T$ receive antennas, we have $\mathbf{v} = \mathbf{A} \mathbf{u} + \mathbf{v}$, where $\mathbf{v} \in \mathbb{C}^{n_r \times 1}$ is the white Gaussian noise, with $E[\mathbf{v} \mathbf{v}^H] = I_{n_r} \sigma_n^2$. The mutual information can be calculated by

$$\Psi(\mathbf{u}; \mathbf{v}) = H(\mathbf{v}) - H(\mathbf{v}|\mathbf{u}),$$

where $H(\cdot) = -E[\log_2(p(\cdot))]$ is the entropy function, and $p(\cdot)$ represents the Probability Density Function (PDF). The mutual information $\Psi(\mathbf{u}; \mathbf{v})$ can be derived according to [9] as

$$E \left\{ \log_2 \left( \frac{1}{2^{2M_r n_r}} \frac{1}{(2\pi\sigma_n^2)^{n_r}} \sum_{\mathbf{u} \in \mathcal{S}} \exp \left[ - \frac{||\mathbf{v} - \mathbf{A} \mathbf{u}||^2}{2\sigma_n^2} \right] \right) \right\} - n_r \log_2 (2\pi e\sigma_n^2),$$

where $\mathcal{S}$ denotes the set of all possible transmitted symbol vectors, $M_r$ is the number of bits per symbol. In general, Eq. (13) cannot be expressed in a closed form. Nevertheless, it can be evaluated by using Monte-Carlo simulations.

B. Mutual Information based Spatial Frequency Multuser Scheduling

For localized OFDMA downlink multiuser MIMO transmission, each OFDMA downlink transmission sub-frame can be partitioned into several RBs to facilitate multiple user packet scheduling [1]. Let $I_{RB,i}$ be the index set of RBs assigned to the user's data is transmitted by distributed subcarriers [1].
user \(i\) within one sub-frame and \(|I_{RB,i}|\) be the length, the number of total RBs in one sub-frame is \(|I_{RB}|\). Then \(|I_{RB}| = |I_{sub,i}|\). Multiple contiguous RBs can be assigned to one user within one sub-frame.

Denote by \(\phi_j\) the \(j\)th set of \(K\) users which are selected from the total \(K_T\) users in the system and let \(\Phi\) be the whole set of \(K\) users chosen from total \(K_T\) users, \(\phi_j \in \Phi, \forall j \in \{1, 2, \cdots, |\Phi|\}\), where \(|\Phi|\) is the size of \(\Phi\), and \(|\Phi| = \binom{K_T}{K}\).

Let us define \(U_j(\phi)\) as the utility function for the \(j\)th RB. As will be shown later, \(U_j(\phi)\) is a function of the MIs of the scheduled users. The objective is to maximize the utility function by selecting the users group with appropriate channel condition and optimizing the power allocated for each user within one subframe. The optimization problem can be described as

\[
\begin{align*}
\max_{\forall \phi \in \Phi} U_j(\phi), \\
\text{s.t.} 1: & \quad I_{sub,i}^k - I_{sub,i}^{k-1} = 1, \\
& \quad \forall k \in \{1, 2, \cdots, |I_{sub,i}| - 1\}, \\
\text{s.t.} 2: & \quad \sum_{n} P_{n,i} \leq P_t^i, \tag{14}
\end{align*}
\]

where the last inequality in (14) specifies the power constraint for user \(i\), \(P_{n,i}\), is the \(k\)th element in the set \(I_{sub,i}\). The subconstraint corresponds to the localised downlink OFDMA transmission, i.e., the user data is transmitted by a group of consecutive subcarriers.

The above optimization problem is to maximize the utility function for each RB subject to the user’s power constraint.

We can define \(U(\phi) = \sum\Psi_i\), where \(\Psi_i\) is the MI for user \(i\), which is defined by Eq. 13. Maximization of this utility function is equivalent to optimization of the maximum achievable rate for systems with a finite alphabet constrained signal constellation. This may result in an unfair situation, i.e., only the users with good channel conditions get resources.

To tackle this problem, we consider a resource fair allocation algorithm for each RB based utility function maximization. The main idea of the fair resource allocation algorithm is to limit the users with more RBs used in a past period \(T_{win}\), and give priority to those users with less transmissions in the period \(T_{win}\).

The algorithm works as follows: Let \(\alpha_{k,i}\) be the moving average of used RBs by the \(i\)th user in the past \(T_{win}\) at interval \(k\) and \(\alpha_{k,i} = (1 - \frac{1}{T_{win}})\alpha_{k-1,i} + \frac{1}{T_{win}}\delta\), where \(\delta = 1\) if the user \(i\) gets scheduled, otherwise \(\delta = 0\). We define the utility function at the \(k\)th interval as \(U_k(\phi) = \sum_{i\in\phi} f(\alpha_{k,i}, \Psi_i, c)\), where \(f(\alpha_{k,i}, \Psi_i, c)\) is a function of \(\alpha_{k,i}\) and \(\Psi_i\), and is defined as \(\Psi_i/\alpha_{k,i}^c\), where \(c\) is a constant. The per RB based scheduling problem then becomes

\[
\phi^* = \arg \max_{\forall \phi \in \Phi} \sum_{i\in\phi} f(\alpha_{k,i}, \Psi_i, c). \tag{15}
\]

Note that the above expression is in fact a generalized Proportional Fair (GPF) scheduling algorithm. When \(c = 1\), it is a traditional Proportional Fair (PF) scheduling algorithm. While in the case of \(c = 0\), it becomes the maximum throughput scheduling algorithm. A value of \(c\) between 0 and 1 represents the trade-off between the maximum throughput scheduling and traditional PF scheduling algorithm.

IV. ANALYTICAL AND NUMERICAL RESULTS

In this section, we present some analytical and numerical results. Here we only consider the case with 2 antennas at the transmitter and 2 receiver antennas at the MS for the SU-MIMO case and single antenna at the MS for the MU-MIMO case. For MU-MIMO, two MSs are grouped together to form a virtual MIMO between MSs and BS. The 3GPP 6-tap Typical Urban (TU6) [1] frequency selective Rayleigh fading channel model with six paths is employed in this work. The TU6 channel has been designed to simulate high delay spread in urban environments. At each Monte-Carlo run, 500 sub-frames are used for data transmission and the power of each user is randomly generated to simulate the fact that users maybe in different locations.

A. Perfect Channel Side Information

Fig. 1 shows the simulation results for the maximum achievable rate in bits/second/Hz versus the number of available users for the downlink MIMO systems with the maximum sum capacity and the maximum sum MI based spatial scheduling algorithm. The transmitted symbols are selected from the QPSK signal constellation and the transmitted SNR is 10 dB. Random user Pairing Scheduling (RPS) algorithm described in [10] is also investigated for a baseline comparison. For random pairing scheduling, the first user is selected in a round robin fashion, while the second user is randomly selected from the rest of the users in the system. It can be seen that as the number of users increases, the multiuser diversity gain can be achieved for all the investigated systems except the one with the RPS algorithm. The reason is that those non-random pairing schedulers have more freedom to choose the MSs with good channel condition and multiuser diversity can thus be exploited. It can also be seen that with the maximum sum capacity based scheduling, the maximum achievable rate is higher than the one with the MI based scheduling algorithm. Since MI is obtained under the signal constellation constraint, the performance of MI based scheduling algorithm is much closer to a real system. On the other hand, maximum sum capacity based scheduling algorithm assumes that the input source is Gaussian distributed, which is unrealistic in a practical system. We can conclude that the commonly used sum capacity scheduling algorithm is too optimistic for practical applications, this is especially true for channels with high SNRs. Both scheduling algorithms rely on the computation of the received SINR. For the MI based scheduling, the received SINR is used to map the pre-calculated MI table; while for the capacity based scheduling, it is used to compute the Shannon capacity based on Shannon capacity formula. The complexity of the MI based scheduling is roughly the same as the sum capacity based scheduling. From the figure, we can also see that the resource fair scheduling algorithm performs slightly better than the traditional PF scheduling algorithm.

B. Limited feedback Channel

The sum rate performance for capacity and MI based scheduling algorithms with the limited feedback channel is shown in Figs. 2 and 3, respectively. In both cases, the transmitted SNR is equal to 10 dB. In these two figures, we also show results for the linearly precoded MU-MIMO systems with the precoding matrices obtained by using the full channel side informa-
tion. Different from the previous multiuser MIMO scheduling investigation with the full channel state information, where the interference from other users can be removed by properly designing the precoding matrix, we do not intend to remove multiuser interference, instead, we schedule multiple users and form a virtual MIMO between the BS and the scheduled users. In the full channel side information case, we assume that the BS has full CSI for all the scheduled users, and the precoding matrix is designed based on such a virtual MIMO CSI.

Our preliminary studies showed that the BER performance for a 6-bit feedback channel is only slightly better than a 3-bit feedback channel, therefore, in our simulation, we only consider the 3-bit feedback channel. It can be seen from Figs. 2 and 3 that the sum rate performance for linearly precoded MIMO systems with the precoding matrix designed based on full CSI is always better than the one for limited feedback channel. However, assuming full channel information at transmitter is unrealistic in practice. The figures also show that the loss in sum rate performance due to limited channel feedback is only within 0.1 bits/s/Hz for the capacity and MI based scheduling algorithms.

V. CONCLUSIONS

In this paper, we analyzed multiuser downlink spatial scheduling algorithms for linearly precoded SDM MIMO schemes. A MI based spatial frequency domain scheduling algorithm is investigated and compared with the Shannon capacity based sum rate scheduling algorithm. The comparison has been made under the condition that the two systems have the same transmission rate or spectral efficiency. In general, with MI based scheduling algorithms, the sum rate of the paired users is much closer to that of the practical system than capacity based scheduling algorithms. The latter usually gives too optimistic sum rates, by which the scheduler always selects the users with the highest SNRs. Whereas with MI based scheduling, when the received SNRs are larger than a certain value, the sum rate of the users is limited by the signal constellation. No matter how high the SNRs of the users are, the sum rate of these users converges to a constant value. In such a case, the scheduler just randomly pairs the users for transmission, thus, it can provide fairness compared with the capacity based scheduling algorithms.

REFERENCES