An Efficient Transmission Scheme with Limited Feedback in Multiuser MIMO Systems

Yubo Yang1,2, Lin Tian1, Jihua Zhou1,2, Yi Sun1, Jinglin Shi1, Zhongcheng Li1
1 Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China
2 Graduate University of Chinese Academy of Sciences, Beijing, China
Email: {yyb, tianlindd, jhzhou, sunyi, sjl, zcil}@ict.ac.cn

Abstract—In this paper, a singular value decomposition based signature matrix inversion (SVD-SI) scheme is proposed for downlink in multiuser MIMO systems, which is more efficient and able to reduce the feedback overhead by limited feedback. The wireless channels are decomposed into several eigenmodes with the right singular vectors as the spatial signatures, which are quantized and fed back to the base station. Then, the operating users are selected according to their signatures, and the multiuser interference is eliminated by the signature matrix inversion scheme. Finally, we characterize the performance of SVD-SI under limited feedback, and give the recommended feedback rate under different scenarios. Numerical results show that the proposed scheme achieves significant throughput improvement while reducing the feedback overhead.

I. INTRODUCTION

Multiple-input Multiple-output (MIMO) has been acknowledged as a promising technique for next generation of mobile communication systems to achieve dramatic improvement in the capacity of wireless communication systems [1].

Multiuser MIMO systems have received significant research interest because of the spectral efficiency improvement and potential for commercial application in wireless systems [2]-[7]. In [2], it was shown that the information-theoretic capacity in MIMO systems can be achieved through dirty paper coding (DPC). A suboptimal but less complex scheme, known as block diagonalization (BD), was introduced for downlink in [3], where a precoding matrix was generated for each user to eliminate the multiuser interference. Although the BD scheme is an effective method for spatial multiplexing, it is not easy to group users because of the lack of spatial signatures in BD scheme. [4] proposed a transmission scheme, where the right singular vectors of the wireless channels were considered as spatial signatures and a greedy power allocation scheme was introduced. However, the multiuser interference in the above scheme made the power allocation problem more complicated since it was not eliminated. In [5], the authors introduced an scheme for uplink, where the left singular vectors were considered as the spatial signatures and a parallel interference cancelation (PIC) was used to eliminate the multiuser interference. Since the receivers can not use PIC without the signals from other users, the above scheme cannot be extended to downlink scenarios. In addition, the above schemes assumed the perfect channel state information at the transmitter (CSIT), which is highly unrealistic especially in FDD (frequency-division duplexing) systems.

When the base station does not have any channel knowledge, the sum rate loss compared to perfect CSIT cases is substantial. To resist the performance loss, partial CSI schemes have been studied recently [6]-[7], where the partial CSI can be modeled as there is a bandwidth constraint on the feedback channel, which is only able to communicate a finite number of feedback bits per block. In [6], an adaptive modulation scheme with transmit beamforming was introduced to maximize the point-to-point channel capacity subject to bandwidth constraints on the feedback channel. However, it did not take the multiuser interference into account. In [7], the sum rate performance of zero-forcing dirty paper coding scheme and channel inversion scheme was studied under the limited feedback model and the shape feedback model. The above scheme characterized the performance under partial CSI, nevertheless it imposed limitations on the system, where the receivers only have one antenna and the number of receivers must equal the number of transmit antennas.

In this paper, we propose a singular value decomposition based signature-matrix inversion (SVD-SI) scheme for downlink transmission in multiuser MIMO/OFDM systems. The wireless channel is decomposed into eigenmodes or virtual channels through singular value decomposition. Then, a user group algorithm is proposed to select the operating users, whose interference to each other is eliminated by the signature-matrix inversion scheme. Afterwards, the power allocation scheme is formulated and solved by a modified water-filling algorithm. Finally, we propose a limited feedback scheme for SVD-SI to reduce the feedback signaling overhead, and study its performance. The performance and properties of our proposed scheme were verified through simulations.

II. SYSTEM MODEL

Consider a downlink multiuser MIMO system with a single base station (BS) equipped with $M_t$ transmit antennas, and $K$ users, each equipped with $M_r$ receive antennas. The frequency band is assumed to be flat fading and block fading. Denote the channel matrix of user $k$ by an $M_r \times M_t$ matrix $H_k$, then the signals received by user $k$ can be expressed as:

$$y_k = H_k x + n_k,$$  
(1)

where $x$ and $y_k$ denote the transmitted signal vector and the received signal vector, respectively, $n_k$ represents a $M_r \times 1$
noise vector, with each entry being i.i.d. complex Gaussian with variance $\sigma_n^2$.

The transmission over a MIMO channel can be converted to a number of parallel virtual channels or channel eigenmodes through singular value decomposition (SVD) of the channel matrix [8], which is expressed as:

$$H_k = U_k \Sigma_k V_k^\dagger = \sum_{i=1}^{\text{rank}(H)} u_{k,i} \sigma_{k,i} v_{k,i}^\dagger, \quad (2)$$

where $u_{k,i}$ and $v_{k,i}$ are the $i$th left and right singular vector respectively, $\sigma_{k,i}$ is the $i$th singular value, and $\dagger$ means conjugate transpose. An eigenmode corresponds to the transmission using a pair of right and left singular vectors as transmit and receive antenna weights, respectively, and $\sigma$ is the equivalent channel gain. We choose the eigenmode with the largest $\sigma$ for user $k$ as its transmission eigenmode, i.e. the “best” eigenmode for user $k$. In the rest of this paper, we denote the singular value, the left and right singular vector of the transmission eigenmode for user $k$ as $\sigma_k$, $u_k$ and $v_k$, respectively.

Then, the transmitted vector is generated as

$$x = \sum_{k=1}^{K} v_k x_k, \quad (3)$$

where $x_k$ is transmitted data of user $k$. According to (1), (2) and (3), the received signal by user $k_1$ is

$$y_{k_1} = \sum_{k_2=1}^{K} U_{k_1} \Sigma_{k_1} \mathbf{R}_{k_1,k_2} x_{k_2} + n_{k_1}, \quad (4)$$

where $\mathbf{R}_{k_1,k_2}$ is a $M_t \times 1$ column vector, with the $i$th entry being $\rho_{k_1,k_2} = v_{k_1,i}^\dagger v_{k_2,i}$, which represents the correlation between the $i$th eigenmode of user $k_1$ and the transmission eigenmode of user $k_2$. Decoding with the left singular vector, user $k_1$ has

$$\hat{x}_{k_1} = u_{k_1}^\dagger y_{k_1} = \sigma_{k_1} (x_{k_1} + \sum_{k_2=1}^{K} \rho_{k_1,k_2} x_{k_2}) + \hat{n}_{k_1}, \quad (5)$$

as the estimation of signal $x_{k_1}$, where $\hat{n}_{k_1} = u_{k_1}^\dagger n_{k_1}$, and $\rho_{k_1,k_2} = v_{k_1,i}^\dagger v_{k_2,i}$ is the correlation between the transmission eigenmodes of user $k_1$ and $k_2$.

In equation (5), it is obvious that the data transmitted to other users provide interference with factors of corresponding $\rho$. A close observation of (4) and (5) indicates that the transmitter only need to be aware of the right singular vector of every user, which can be considered as its spatial signature. According to $v_k$ of every user, the transmitter can reduce the multiuser interference by appropriately selecting operating users. Afterwards, the multiuser interference between the operating users has to be eliminated. In following section, we present a singular value decomposition based signature-matrix inversion scheme (SVD-SI) to eliminate the multiuser interference.

III. SVD-SI AND LIMITED FEEDBACK

A. SVD-SI Scheme

From (4) and (5), it is indicated that the transmitted data is spread in space domain by the spatial signature $v_k$. If the signatures are mutually orthogonal, then the transmitted signals of different users will not interfere with each other after the receiver decoding. However, in most cases, the spatial signatures are not mutually orthogonal, i.e., $|\rho_{k_1,k_2}| > 0$ for $k_1 \neq k_2$, which causes multiuser interference and makes the power allocation problem more complicated. To eliminate the multiuser interference, we focus on the precoding method at transmitter, where the transmitting signal is generated using a precoding matrix $W$ instead of $v_k$:

$$x = \sum_{k=1}^{K} w_k x_k = W s, \quad (6)$$

where $w_k$ is a $M_t \times 1$ column vector, $W = [w_1 w_2 ... w_K]$ is the precoding matrix, and $s = [x_1 x_2 ... x_K]^\dagger$ is the data vector. Substituting $w_k x_k$ for $v_k x_k$ in (4) and (5), the estimation of data $x_k$ is given by

$$\hat{x}_{k_1} = u_{k_1}^\dagger (U_{k_1} \Sigma_{k_1} V_{k_1}^\dagger \sum_{k_2=1}^{K} w_{k_2} x_{k_2} + n_{k_1}) = \sigma_{k_1} u_{k_1}^\dagger w_{k_1} x_{k_1} + \sigma_{k_1} \sum_{k_2=1}^{K} v_{k_1}^\dagger w_{k_2} x_{k_2} + \hat{n}_{k_1}. \quad (7)$$

To eliminate all multiuser interference, we impose the constraints that $v_{k_1}^\dagger w_{k_2} = 0$ for $k_1 \neq k_2$ and $v_{k_1}^\dagger w_{k_1} = 1$. Denote $V = [v_1 v_2 ... v_K]^\dagger$ as the spatial signature matrix, and $W = [w_1 w_2 ... w_K]^\dagger$ as the precoding matrix. If $M_t = K$, the constraints is equivalent to $W = V^{-1}$, since $V$ has full rank with probability one under i.i.d. Rayleigh fading [7]. When $M_t > K$, the precoding matrix is the pseudoinverse of the signature matrix, i.e. $W = V^\dagger (VV^\dagger)^{-1}$.

If the number of transmit antennas is less than that of users, i.e. $M_t < K$, $M_t$ users should be selected as the operating users. However, if the spatial signatures of the selected users are highly correlated, they will cause severe multiuser interference to each other, and thus degrade the system performance. To solve this problem, we propose an user selection algorithm in next section, which avoids the severe multiuser interference by measuring the spatial correlation among the users.

Compared with the BD algorithm, SVD-SI is more efficient. For $M_t$ operating users, the BD algorithm needs $2M_t SVD$ operations, whereas the SVD-SI scheme only needs $M_t SVD$ operations and a matrix inversion operation. As a result, the computation cost of SVD-SI is almost only a half of BD algorithm. In addition, the base station only needs to know the right singular vector of each user, thus the feedback information can be reduced significantly, whereas the full CSI is fed back to the base station for BD algorithm.
B. User Selection Algorithm

From (5), $\rho_{k_1k_2}$ characterizes the correlation between user $k_1$ and $k_2$. Therefore, we can select the operating users according to their spatial correlations between each other.

The basic idea of the user selection algorithm is to choose the user which generates the least interference to other selected users. Firstly, we compute the spatial correlation $\rho_{k_1k_2}$ for each pair of users, which characterizes the multiuser interference according to (5). The first user is selected randomly or according to other metrics, such as channel quality or QoS (Quality of Service) requirements. Denote the set of users as $\mathcal{G} = \{1, 2, ..., K\}$ and the set of selected users as $\mathcal{G}_s$. Then, the user selection algorithm can be expressed as

$$i = \arg\min_{k_1 \in \mathcal{G}/\mathcal{G}_s} \left( \sum_{k_2 \in \mathcal{G}_s} |\rho_{k_1k_2}|^2 \right), \quad (8)$$

where $i$ is the selected user in the current step. As a result, the user selected in every step generates the least interference to other selected users.

C. Adaptive Power Allocation

After the elimination of multiuser interference, the estimation of data $x_k$ is expressed as

$$\hat{x}_{k_1} = \sigma_k v_{k_1}^\dagger w_{k_1}^T x_{k_1} + \sigma_k \sum_{k_2, k_2 \neq k_1} v_{k_2}^\dagger w_{k_2}^T x_{k_2} + \tilde{r}_{k_1}, \quad (9)$$

with the transmitting power of data $x_{k_1}$ is

$$p_{k_1} = w_{k_1}^T w_{k_1} p_{k_1}, \quad (10)$$

where $p_{k_1}$ is the power allocated to user $k_1$. Thus, the SINR of data $x_{k_1}$ is given by $\Gamma_{k_1} = \frac{\sigma_k^2 p_{k_1}}{\sigma_n^2}$, where $\sigma_n^2$ is the noise power. If MQAM is employed, the available data rate $r_{k_1}$ for user $k_1$ is given by [9]

$$r_{k_1} = \log_2(1 + \frac{1.6}{\ln 5\beta\text{ER}} \Gamma_{k_1}). \quad (11)$$

The power resource allocation problem is to allocate the total power between the $M_t$ operating users to achieve maximum system data rate. Based on the above definitions, the problem is formulated as follows:

$$f = \arg\max_{p_k} \sum_{k \in \mathcal{G}_s} \log_2(1 + \frac{1.6}{\ln 5\beta\text{ER}} \Gamma_k) \quad (12a)$$

subject to

$$\sum_{k \in \mathcal{G}_s} w_k^T w_k p_k \leq P_T; \quad (12b)$$

$$p_k \geq 0; k \in \mathcal{G}_s. \quad (12c)$$

Substituting $p_{k_1}^*$ in (10) for $p_{k_1}$, the problem (12) is transformed into

$$f' = \arg\max_{p_k} \sum_{k \in \mathcal{G}_s} \log_2(1 + \frac{1.6}{\ln 5\beta\text{ER}} \sigma_n^2 p_k^* \sigma_k^2) \quad (13a)$$

subject to

$$\sum_{k \in \mathcal{G}_s} p_k^* \leq P_T; \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \ql
according to the quantized vectors $Q_C(v_k)$. Denote the quantization error as $\Delta_k = v_k - Q_C(v_k)$ for user $k$. Then, the estimation of data $x_k$ is

\[
\hat{x}_k = u_k^T (U_k \Sigma_k v_k^T \sum_{k_2 \in \mathcal{U}_k} w_{k_2} x_{k_2} + n_k)
\]

\[
= \sigma_k (1 + \Delta_k^T w_{k_2} x_{k_2}) + \hat{n}_k.
\] (17)

The multiuser interference under limited feedback is generated following property. Then, the multiuser interference under limited feedback has according to the quantized vectors

\[
\mathbb{E} \{ x_k^T x_k \} = \frac{P_T}{\|W\|_F^2}.
\] (18)

Then, the multiuser interference under limited feedback has the following property:

**Proposition 1:** If the $M_t$ selected operating users have equal power allocation $\mathbb{E} \{ x_k^T x_k \} = P_T/\|W\|_F^2$, the expectation of the multiuser interference power for user $k$ is

\[
\mathbb{E} \{ \Delta_k^T \Delta_k \} = \sigma_k^2 D_C P_T \frac{M_t - 1}{M_t^2}.
\]

**Proof:** According to (17), the power expectation of the multiuser interference for user $k$ is expressed as

\[
\mathbb{E} \{ \Delta_k^T \Delta_k \} = \sigma_k^2 \sum_{k_2 \in \mathcal{U}_k} \sum_{k_2 \neq k_1} \left( \Delta_k^T w_{k_2} x_{k_2} \right) \left( \Delta_k^T w_{k_2} x_{k_2} \right)
\]

\[
= \sigma_k^2 \mathbb{E} \sum_{k_2 \in \mathcal{U}_k} \sum_{k_2 \neq k_1} \left( x_{k_2}^T w_{k_2} \Delta_k \right)^T \left( \Delta_k^T w_{k_2} x_{k_2} \right)
\]

According to (15) and (18), we have

\[
\mathbb{E} \{ \Delta_k^T \Delta_k \} = \sigma_k^2 D_C P_T \frac{M_t - 1}{M_t^2}.
\]

Since the channel matrix for every user is i.i.d. distributed, we achieve $\mathbb{E} \{ w_k^T w_i \} = \mathbb{E} \{ w_j^T w_j \}$. So we have:

\[
\mathbb{E} \{ \Delta_k^T \Delta_k \} = \sigma_k^2 D_C P_T \frac{M_t - 1}{M_t^2}.
\]

**Proposition 2:** As the total power $P_T$ increases to infinity, the average data rate of user $k_1$ and the average system sum data rate are upper bounded.

**Proof:** According to (17), the average signal power for data of user $k_1$ is

\[
\mathbb{E} \{ \sigma_k^2 \| x_k \|^2 \} = \sigma_k^2 (P_T D_C P_T + \frac{1}{M_t^2} + \frac{1}{M_t})
\]

\[
\leq \sigma_k^2 M_t (1 + D_C) + \frac{D_C}{M_t^2},
\]

where $\|W\|^2_F \geq M_t (1 + D_C)$. Combining this and the result of Proposition 1, the average SINR of user $k_1$ under limited feedback is given as

\[
\mathbb{E} \{ \Gamma_k \} \leq \frac{\sigma_k^2 M_t (1 + D_C) + \frac{D_C}{M_t^2}}{\sigma_k^2 D_C P_T M_t - 1} + \sigma_k^2.
\]

From Jensen’s inequality, the average achievable data rate of user $k_1$ is upper bound as [9]

\[
\mathbb{E} \{ r_k \} \leq \mathbb{E} \{ \log_2 (1 + \frac{1}{5BEP} \Gamma_k) \}
\]

\[
\leq \log_2 (1 + \frac{1}{5BEP} \Gamma_k).
\]

As $\lim_{P_T \to \infty} \mathbb{E} \{ \Gamma_k \} = \frac{M_t (1 + D_C)}{D_C (M_t - 1)}$, we have

\[
\lim_{P_T \to \infty} \mathbb{E} \{ r_k \} \leq \log_2 (1 + \frac{1.6}{5BEP} \frac{M_t (1 + D_C)}{D_C (M_t - 1)}).
\]

Since user $k_1$ is randomly selected, the asymptotical average sum data rate is upper bounded by

\[
\lim_{P_T \to \infty} \mathbb{E} \{ R_i \} \leq M_i \log_2 (1 + \frac{1.6}{5BEP} \frac{M_t (1 + D_C)}{D_C (M_t - 1)}).
\]

As a result, the system data rate experience a sum rate upper bound for limited feedback, which was verified in the simulation.

**IV. Simulation Results**

The performance of the proposed algorithms was studied by simulations. In all cases, the users’ channels were assumed to be constant during a time slot. We considered a single cell with a base station equipped with $M_t = 4$ transmit antennas and $K = 32$ users, each equipped with $M_r = 4$ receive antennas. The elements of channel matrices were independent complex Gaussian random variables with zero mean and unit variance. Normalizing the noise power as one, the SNR in the figures is SNR $= 10 \log_{10} P_T$, where $P_T$ is the total power.

Fig. 1 shows the data rates as a function of SNR. The data rates of SVD-SI with perfect CSIT, 30 bits feedback and 60 bits feedback are compared with that of BD algorithm [3], where the operating users are selected randomly for BD algorithm. As shown in Fig. 1, the SVD-SI under perfect CSIT achieves the largest data rate, which is 30% larger.
with the BD algorithm our proposed scheme results in significant throughput improvement while reducing the feedback overhead.

V. CONCLUSION

In this paper, we studied the transmission problem in multiuser MIMO systems. A singular value decomposition based signature-matrix inversion (SVD-SI) scheme was proposed to select the operating users and eliminate the multiuser interference between them. Using SVD-SI scheme combined with vector quantization, the base station only needs partial CSIT to achieve a better performance in multiuser MIMO systems. We also studied the characteristics of SVD-SI scheme under limited feedback, and derived the upper bound. Numerical results show that the proposed scheme can results in significant improvement in channel efficiency while reducing the feedback overhead.

REFERENCES