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Mimo Based Downlink Channels with Limited Feedback and User Selection Using Th Precoding Technique

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Abstract
The implementation of Tomlinson-Harashima (TH) pre-coding for multiuser MIMO systems based on quantized channel state information (CSI) at the transmitter side. Compared with the results in [1], our scheme applies to more general system setting where the number of users in the system can be less than or equal to the number of transmit antennas. We also study the achievable average sum rate of the proposed quantized CSI-based TH pre-coding scheme. The expressions of the upper bounds on both the average sum rate of the systems with quantized CSI and the mean loss in average sum rate due to CSI quantization are derived. We also present some numerical results. The results show that the nonlinear TH pre-coding can achieve much better performance than that of linear zero-forcing pre-coding for both perfect CSI and quantized CSI cases. In addition, our derived upper bound on the mean rate loss for TH pre-coding converges to the true rate loss faster than that of zero-forcing pre-coding obtained in [2] as the number of feedback bits becomes large. Both the analytical and numerical results show that nonlinear pre-coding suffers from imperfect CSI more than linear pre-coding does.
***Keywords*:** Tomlinson-Harashima pre-coding, QR decomposition, random vector quantization, zero-forcing,

I. INTRODUCTION

Since the pioneering work [3] and [4], multiple-input multiple-output (MIMO) communication systems have been extensively studied in both academic and industry communities and becomes the key technology of most emerging wireless standards. It is shown that significantly enhanced spectral efficiency and link reliability can be achieved compared with conventional single antenna systems [3, 5]. In the downlink multiuser MIMO systems, multiple users can be simultaneously served by exploiting the spatial multiplexing capability of multiple transmit antennas, rather than trying to maximize the capacity of a single-user link. The performance of a MIMO system with spatial multiplexing is severely impaired by the multi-stream interference due to the simultaneous transmission of parallel data streams. To reduce the interference between the parallel data streams, both the processing of the data streams at the transmitter (pre-coding) and the processing of the received signals (equalization) can be used. Pre-coding matches the transmission to the channel. Accordingly, linear pre-coding schemes with low **Givens transformation.** Complexity is based on zero-forcing (ZF) [6] or minimum mean-square-error (MMSE) criteria [7] and their improved version of channel regularization [8]. In spite of very low complexity, the linear schemes suffer from capacity loss. Nonlinear processing at either the transmitter or the receiver provides an alternative approach that offers the potential for performance improvements over the linear approaches. This kind of approaches includes schemes employing linear pre-coding combined with decision feedback equalization (DFE) [5, 9], vector perturbation [10], Tomlinson-Harashima (TH) pre-coding [1, 11], and ideal dirty paper coding [12, 13] which is too complex to be implemented in practice.

Vector perturbation has been proposed for multiuser MIMO channel model and can achieve rate near capacity [10]. It has superior performance to linear pre-coding techniques, such as zero-forcing beam forming and channel inversion, as well as TH pre-coding [10]. However, this method requires the joint selection of a vector perturbation of the signal to be transmitted to all the receivers, which is a multi-dimensional integer-lattice least-squares problem. The optimal solution with an exhaustive search over all possible integers in the lattice is complexity prohibited. Although some sub-optimal solutions, such as sphere encoder [14], exist, the complexity is still much higher than TH precoding.TH pre-coding can be viewed as a simplified version of vector perturbation by sequential generation of the integer offset vector instead of joint selection. This technique employs modulo arithmetic and has a complexity comparable to that of linear pre-coders. It was originally proposed to combat inter-symbol Interference in highly dispersive channels [15] and can readily be extended to MIMO channels [1, 16]. Although it was shown in [10] that TH pre-coding does not perform nearly as well as vector perturbation for general SNR regime, it can achieve significantly better performance than the linear pre-processing algorithm, since it limits the transmitted power increase while pre-eliminating the inter-stream interference [11]. Thus, it provides a good choice of trade-off between performance and complexity and has recently received much attention [1, 11]. Note that TH pre-coding is strongly related to dirty paper coding. In fact, it is a suboptimal implementation of dirty paper coding proposed in [17]. As many pre-coding schemes, the major problem for systems with TH pre-coding is the availability of the channel state (CSI) information at the transmitter. In time division duplex systems, since the channel can be assumed to be reciprocal, the CSI can be easily obtained from the channel estimation during reception. In frequency division duplex (FDD) systems, the transmitter cannot estimate this information and the CSI has to be communicated from the receivers to the transmitter.

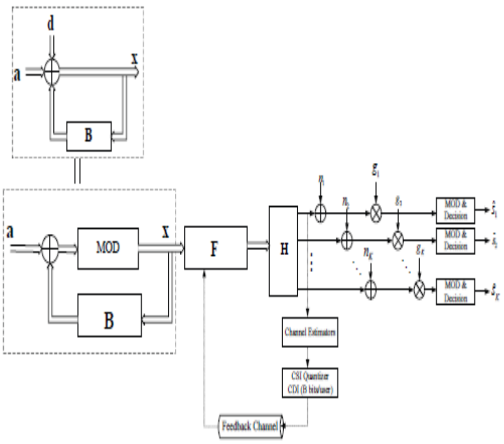


Fig. 1. TH pre-coding for multiuser MIMO downlink with quantized CSI feedback.

A transmitter equipped with multiple antennas communicates with a receiver that has multiple antennas. Most classic pre-coding results assume narrowband, slowly fading channels, meaning that the channel for a certain period of time can be described by a single channel matrix which does not change faster. In practice, such channels can be achieved, for example, through OFDM. Pre-coding strategy that maximizes the throughput called channel capacity depends on the channel information**.**

II. SYSTEM MODEL

MIMO is the use of multiple antennas at both the transmitter and receiver to improve Communication performance. It is one of several forms of smart antenna technology. Note that the term input and output refer to the radio channel carrying the signal, not to the devices having antenna. New techniques, which account for the extra spatial dimension, have been adapted to realize these gains in new and previously existing systems. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power.

In wireless communications, diversity gain is the increase in signal-to-interference ratio due to some diversity scheme, or how much the transmission power can be reduced when a diversity scheme is introduced.

Space–time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal. In fact, space–time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

In practical systems, perfect CSI is never available at the transmitter. For example, in a FDD system, the transmitter obtains CSI for the downlink through the limited feedback of *B* bits by each receiver. Following the studies of quantized CSI feedback in [2, 19], channel direction vector is quantized at each receiver, and the corresponding index is fed back to the transmitter via an error and delay-free feedback channel. Given the quantization codebook which is known to both the transmitter and all the receivers, the *k*-th receiver selects the quantized channel direction vector of its own channel as follow where ¯hk = hk _hk_ is the channel direction vector of user k. In this work, we use RVQ codebook, in which the n quantization vectors are independently and isotropically distributed on the nT –dimensional complex unit sphere. Although RVQ is suboptimal for a finite-size system, it is very amenable to analysis and also its performance is close to the optimal quantization [2]. Using the result in [2], for user k we have ¯h k = ˆhk cos θk + ˜hk sin θk, (11) where cos2 θk = |¯hkˆh Hk |2, ˜hk ∈ C1×nT is a unit norm vector isotropically distributed in the orthogonal complement subspace of ˆhk and independent of sin θk.

Then H can be written as H = Γ _ ΦˆH + Ω˜H _ , (12) where Γ = diag _ ρ1, · · · , ρK _ with ρk = _hk_, Φ = diag (cos θ1, · · · , cos θK) and Ω = diag _ sin θ1, · · · , sin θK _ , ˆH = _ ˆh T1 , · · · ,ˆhT K _T and ˜H = _ ˜h T1 , · · · ,˜hT K _T . For simplicity of analysis, in this work we consider the quantization cell approximation used in [19, 23], where each

quantization cell is assumed to be a Verona region of a spherical cap with surface area approximately equal to 1 n of the total surface area of the nT –dimensional unit sphere. For a given codebook W, the actual quantization cell for vector wi, Ri = _ ¯h : |¯hwi|2 ≥ |¯hwj |2, ∀ i = j _ , is approximated as R˜i ≈ _ ¯h : |¯hwi| ≥ 1 – δ _ , where δ = 2 − B nT −1 . where ¯hk = hk _hk_ is the channel direction vector of user k. In this work, we use RVQ codebook, in which the n quantization vectors are independently and isotropically distributed on the n T –dimensional complex unit sphere.
Although RVQ is sub optimal for a finite-size system.),

III. SYSTEM WITH QUANTIZED TRANSMIT CSI

I will study the achievable average sum rate of the proposed quantized CSI feedback TH pre-coding scheme. Although the exact distribution of each term in the expression of the output SINR γk in can be obtained (see for the detailed information), these terms are located at both the numerator and the denominator. Thus, to obtain the exact closed-form expression of the distribution of output SINR γk can be very difficult if not impossible, not to mention the exact closed-form expression of the average sum rate. Thus, to simplify analysis, we have appealed to studying some bounds of the average sum rate and the average sum rate loss instead of exact results. For tractability, throughout this section we assume each user's channel is Rayleigh-faded. In the following subsection, we will first study the statistical distribution of the power of interference signal at each user caused by quantized CSI.

In this subsection, assuming Rayleigh fading channel and RVQ for quantized CSI feedback, we will derive the statistical distribution of interference part

$$\Delta R_k = \mathbb{E}_{\mathbf{H},\mathbb{W}}\{R_{P,k} - R_{Q,k}\}$$
$$\leq \Delta R = \log_2\left(1 + cP\, 2^{-\frac{B}{n_T-1}}\right)$$
$$+ \frac{\log_2(e)}{n_T - 1}\sum_{i=1}^{n_T-1}\beta\left(n, \frac{i}{n_T-1}\right),$$

P κ ρ2 k _˜**h**k ˆ**Q**H_2 sin2 θk

It is well known that ρ2 k has a χ2 2Nt distribution and the distribution of sin2 θk is given in However, since ˜**h** k ⊥ ˆ**h**k (k = 1, · · ·, K) and ˆ**Q** is determined by ˆ**h**k (k = 1, · · · ,K), ˜**h**k for k = 1, · · ·, K are not independent of ˆ**Q** . The distribution of the term _˜**h**kˆ**Q**H_2 is still unknown and to obtain the exact result is not trivial.

IV. AVERAGE SUM RATE ANALYSIS UNDER QUANTIZED CSI FEEDBACK

We consider the well known Tomlinson-Harashima pre-coder (THP) as the transmit side pre-processor. The block diagram of the THP is shown in figure, the I–G operation in figure essentially performs successive interference cancellation at the transmitter, and the mod (M) operation ensures that the resulting cancelled output values are contained within a certain acceptable range, where M is the cardinality of the modulation alphabet. The matrix G is upper triangular with unit diagonal.

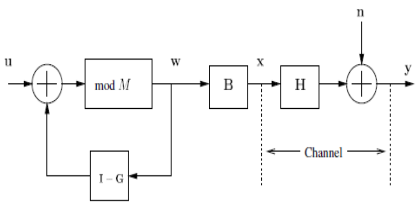


Fig.2 TH pre -coding for multiuser n MIMO downlink with quantized CSI feedback.

The THP design involves the choice of the matrices B and G using the knowledge of the channel matrix H at the transmitter. This choice can be made based on the optimization of certain metrics, such as signal-to-interference ratio (SIR), mean square error (MSE), etc. As mentioned earlier, it is of interest to consider imperfect channel knowledge at the transmitter. Consequently, in the following, we address the problem of choosing B and G for the case of imperfect CSI at the transmitter. The non linear technique employing modulo arithmetic's usually called Tomlinson Harashima pre-coding was introduced independently and almost simultaneously. Tomlinson Harashima pre-coding was originally proposed for use with an M- point one dimensional PAM signal set. The transmitter is equipped with nT transmit antennas and K decentralized users each has a single antenna such that K≤nT.Let the vector s =[s1,···,sK]^T ∈ CK×1 represent the modulated signal vector for all users, where s k is the k-th modulated symbol stream for user k. Here we assume that an M-ray square constellation (Miss a square number) is employed in each of the parallel data streams and the constellation set is

$$A = \left\{ s_I + j s_Q \mid s_I, s_Q \in \pm 1\sqrt{\frac{3}{2(M-1)}}, \pm 3\sqrt{\frac{3}{2(M-1)}}, \cdots, \pm\sqrt{M}\sqrt{\frac{3}{2(M-1)}} \right\}.$$

In general, the average transmit symbol energy is normalized, i.e. E{|sk|}=1

$$\mathrm{MOD}_\tau(x) = x - \tau\left\lfloor \frac{x+\tau}{2\tau} \right\rfloor,$$

$$x_1 = s_1,$$

$$x_k = s_k - \sum_{l=1}^{k-1} [\mathrm{B}]_{k,l} x_l, \ k = 2, \cdots, K.$$

$$x_k = s_k + d_k - \sum_{l=1}^{k-1} [\mathrm{B}]_{k,l} x_l, \ k = 2, \cdots, K,$$

$$\mathbf{v} = \mathbf{C}\mathbf{x},$$

where $\mathbf{v} = [v_1, v_2, \cdots, v_K]^T$ and

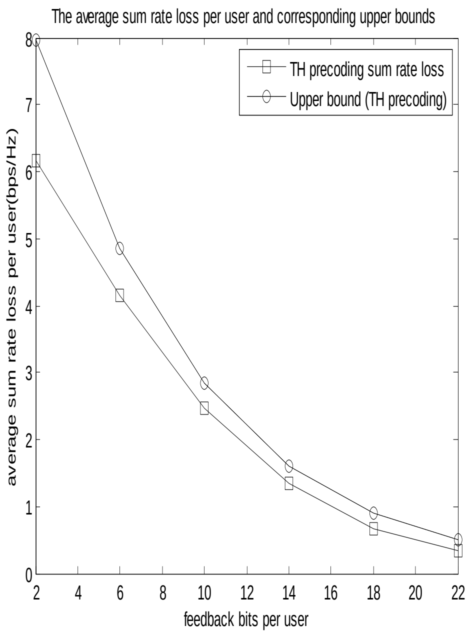
$$\mathrm{C} = \mathrm{B} + \mathrm{I}.$$

$$\mathbf{r} = \sqrt{\frac{P}{\kappa}} \mathbf{HFx} + \mathbf{n},$$

$$\mathbf{y} = \mathbf{G}\left(\sqrt{\frac{P}{\kappa}} \mathbf{HFx} + \mathbf{n}\right),$$

$$\mathbf{y} = \mathbf{v} + \mathbf{Gn}.$$

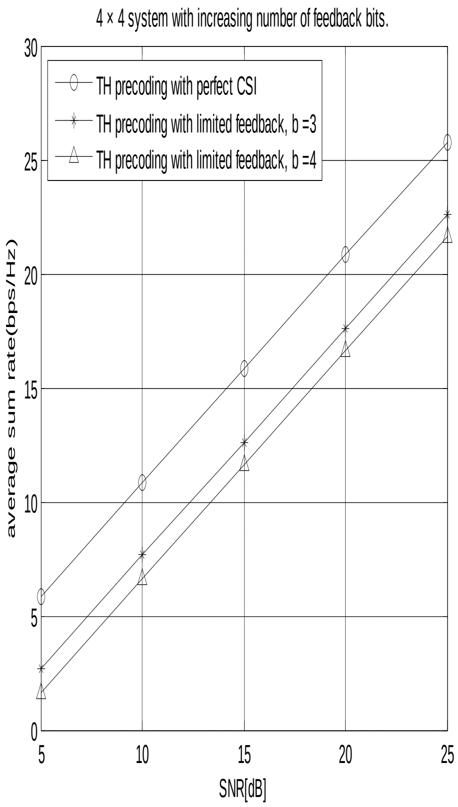
$$\xi_k = \frac{P}{\kappa} |r_{k,k}|^2.$$



V. NUMERICAL RESULTS

In this section we present some numerical results. We assume *nT* = *K* = 4. Here the SNR of the systems is defined to be equal to *P*.

Fig. 3 shows the average sum rate performance of TH pre-coding and linear ZF pre-coding with both perfect CSI and Assume, the average sum rate curves are shown for a system with nT =4and K=4. The feedback rate is assumed to scale according to the relationship given in (24). Notice that, since ε can be set to be a small number when B is large enough, in the simulation we set ε =0 to get a stronger condition than Limited feedback is seen to perform within around4dB and5.5dB of perfect CSI TH pre coding for b=3 and b=4 respectively



VI. CONCLUSION

We have investigated the implementation of TH pre-coding in the downlink multiuser MIMO systems with quantized CSI at the transmitter side. In particular, our scheme generalized the results in to more general system setting where the number of users *K* in the systems can be less than or equal to the number of transmit antennas *nT*. In addition, we studied the achievable average sum rate of the proposed scheme by deriving expressions of upper bounds on both the average sum rate and the mean loss in sum rate due to CSI quantization. Our numerical results showed that the nonlinear TH precoding could achieve much better performance than that of linear zero-forcing precoding for both perfect CSI and quantized CSI cases. In addition, our derived upper bound for TH precoding converged to the true rate loss faster than the upper bound for zero-forcing precoding obtained in as the number of feedback bits increased.

REFERENCE

[1] C. Windpassinger, R. F. H. Fischer, T. Vencel, and J. B. Huber, “Precoding in multiantenna and multiuser communications,” IEEE Trans. Wireless Commun., vol. 3, no. 4, pp. 1305–1316, July 2004.

[2] N. Jindal, “MIMO broadcast channels with finite-rate feedback,” IEEE Trans. Inf. Theory, vol. 52, pp. 5045–5060, Nov. 2006.

[3] I. E. Telatar, “Capacity of multi-antenna Gaussian channels,” Europ. Trans. Commun., pp. 585–595, Nov.-Dec. 1999.

[4] G. J. Foschini and J. E. Hall, “Layered space-time architecture for wireless communication in a fading environment when using multielement antennas,” Bell Labs Tech. J., pp. 41–59, 1996.

[5] P. W. Wolniansky, G. J. Foschini, G. D. Golden, and R. A. Valenzuela, “V-BLAST: an architecture for realizing very high data rates over the rich-scattering wireless channel,” in Proc. 1998 URSI Int. Symposium on Signals, Systems, and Electronics, pp. 295–300.

[6] T. Haustein, C. von Helmolt, E. Jorswieck, V. Jungnickel, and V. Pohl, “Performance of MIMO systems with channel inversion,” in Proc. 2002 IEEE Veh. Technol. Conf. – Spring, pp. 35–39.

[7] M. Joham, K. Kusume, M. H. Gzara, and W. Utschick, “Transmit Wiener filter for the downlink of TDD DS-CDMA systems,” in Proc. 2002 IEEE Symp. Spread-Spectrum Technol., Applicat., pp. 9–13.

[8] C. B. Peel, B. M. Hochwald, and A. L. Swindlehurst, “A vector-perturbation technique for near-capacity multiantenna multi-user communication—part I: channel inversion and regularization,” IEEE Trans. Commun., vol. 53, no. 1, pp. 195–202, Jan. 2005.

[9] J. Yang and S. Roy, “Joint transmitter-receiver optimization for multiinput multi-output systems with decision feedback,” IEEE Trans. Inf. Theory, vol. 40, no. 5, pp. 1334–1347, Sep. 1994.

[10] B. M. Hochwald, C. B. Peel, and A. L. Swindle hurst, “A vector-perturbation technique for near-capacity multiantenna multiuser communication—part II: perturbation,” IEEE Trans. Commun., vol. 53, no. 3, pp. 537–544, Mar. 2005.

[11] R. F. H. Fischer, Precoding and Signal Shaping for Digital Transmission, 1st edition. Wiley, 2002.

[12] M. Costa, “Writing on dirty paper,” IEEE Trans. Inf. Theory, vol. 29, no. 1, pp. 439–441, May 1983.

[13] H.Weingarten, Y. Steinberg, and S. Shamai (Shitz), “The capacity region of the Gaussian multiple-input multiple-output broadcast channel,” IEEE Trans. Inf. Theory, vol. 52, no. 9, pp. 3936–3964, Sep. 2006.

[14] M. O. Damen, A. Chkeif, and J.-C. Belfiore, “Lattice code decoder for space-time codes,” IEEE Commun. Lett., vol. 4, pp. 161–163, May 2000.

[15] H. Harashima and H. Miyakawa, “Matched-transmission technique for channels with intersymbol interference,” IEEE Trans. Commun., vol. 20, pp. 774–780, Aug. 1972.

[16] A. A. D’Amico, “Tomlinson-Harashima precoding in MIMO systems: a unified approach to transceiver optimization based on multiplicative schur-convexity,” IEEE Trans. Signal Process., vol. 56, no. 8, pp. 3662– 3677, Aug. 2008.