AN IMPROVED THROUGHPUT FOR REGULARIZED TOMLINSON-HARASHIMA PRECODING IN MULIUSER MIMO DOWNLINK

[1] MR.ANIRUDDH H. AMIN, [2]MS. ASHA N. PATEL

[1] *Asst. Professor, Department of E & C Engineering, V.I.C.T., Gandhi agar, Gujarat*
[2]M.E. [Electronics & Communication Engg.] Student, Department Of E & C Engineering, SIRT, Bhopal

aniruddh101@yahoo.com, a1_patel86@yahoo.com

ABSTRACT: *Tomlinson-Harashima precoding (THP) is considered as a prominent precoding scheme due to its capability to efficiently cancel out the known interference at the transmitter side. Therefore, the throughput rates achieved by THP are superior to those achieved by conventional linear precoding schemes. In this paper, a simulated comparative approach on the error rate for the regularized THP scheme under ZF-THP and MMSE-THP with multiuser interference is derive for QPSK and 16 QAM modulation scheme. Analytical results show the QPSK performance derived in this paper is tighter than the 16 QAM particularly for a SNR range.*

Keywords—Multi user MIMO, SDMA, THP, Tomlinson Harashima, pre-coding, ZF, MMSE, QPSK, QAM.

I: INTODUCTION

In recent years, there has been a considerable interest in wireless multiple-input, multiple output (MIMO) communication systems because of their promising improvement in terms of performance and bandwidth efficiency [1], [2], [3], [4], [5]. An important research topic is the study of multiuser (MU) MIMO systems. Such systems have the potential to combine the high throughput achievable with MIMO processing with the benefits of space division multiple access (SDMA). Multiple-input multiple-output (MIMO) communication techniques have been an important research topic due to their potential for high capacity, increased diversity, and interference suppression. For applications such as wireless LANs and cellular telephony, MIMO systems will likely be deployed in environments where a base station (BS) [write no.] simultaneously communicates with many users. As a result, the study of multiuser [11] MIMO (MU-MIMO) systems has recently emerged as an important research topic. Such systems have the potential to exploit the high capacity achievable by MIMO processing and combine this with the benefits of space division multiple access (SDMA).

In MU-MIMO downlink, spatial multiplexing schemes are adopted at the transmitter, where parallel transmission of independent data streams introduces severe interlayer interference. Since the mobiles are decentralized and non cooperative, conventional MIMO detection algorithms, such as zero-forcing (ZF), minimum mean square error (MMSE) or decision-feedback detection (DFE), cannot work efficiently. An alternative solution is dirty paper coding (DPC), where the detection structure is moved from the receiver side to the transmitter side. Thus, as the streams of different users are perfectly known at the transmitter, i.e., BS, they can be cancelled out such that each user receives only his own stream.

DPC was first described by Costa for the Gaussian Interference channel [6], where the capacity of an Interference channel (and the interfering signals are known at the transmitter) is shown to be the same as that of the interference free channel. Recently, DPC has emerged as a building block in multiuser broadcast over MIMO channels, as initiated in [7].

The simplest pre-coding algorithm for MU-MIMO systems is the well-known matrix inversion, i.e., zero-forcing pre-coding. By treating the transmitted signal vector with the pseudo-inverse of the channel matrix, the mutual interference among users is perfectly cancelled out [8]. Nevertheless, for an ill-conditioned channel, the transmit power is not fairly distributed among users, resulting in degradation in the system performance. Regularized channel inversion, i.e., MMSE pre-coding, avoids the noise amplification by improving the conditionality of the channel matrix. Although the sum capacity of linear MMSE pre-coding is linear in terms of the number of users, it is still far from the Shannon sum capacity of MIMO systems [9].

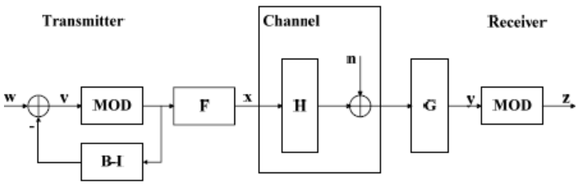

Fig. 1.1 Structure of MU-MIMO system employing Tomlinson-Harshima Precoding

Tomlinson-Harashima pre-coding (THP) achieves close to capacity sum rates [5]. The performance and capacity of THP based on the ZF criterion (THP-ZF) are shown to be superior to those of the linear pre-coding algorithms. Thus, employing the THP with the MMSE performance-based criterion (THP-MMSE) achieves close to the MIMO capacity in absence of interference. In this paper, we are interested in the achievable sum information rates by the THP-MMSE algorithm due to its potential to increase the channel capacity.

The remainder of this paper is organized as follows. First, Tomlinson-Harashima pre-coding is reviewed in Section II. In Section III, we derive the equation for Tomlinson Harashima pre-coding. Simulation results are given in Section IV. Finally, conclusions are drawn in Section V.

II: TOMLINSON-HARASHIMA PRECODING FOR MULTIUSER MIMO SYSTEMS

In this paper, we assume that the transmitter has perfect knowledge of the channel state information (CSI) via feedback from users. There are *N* transmit antennas deployed in the base station (BS), and *M* non-cooperative mobile stations (MS) simultaneously communicating with the BS. Each MS has one receive antenna. The structure of communication system using THP in multiuser MIMO downlink is shown in Figure 1. The symbol vector $\mathbf{w} = (\mathbf{w_1}, \mathbf{w_2}, \ldots, \mathbf{w_M})^T$ is the data vector to be transmitted symbols are independent and they have unit average power, i.e. $E[ww^H] = I$, where **I** denotes the identity matrix.

In **Figure 1.1**, the THP transmitter consist of a feed-forward filter **F** and feedback filter **(B-I). The feedback filter B-I)** transforms the interference into a causal form thus the interference can be eliminated by the feedback filter **B-I).** Note that the diagonal elements of the lower triangular matrix **B** should be all 1s. Both the feed-forward and feedback filters are obtained via the **LQ** decomposition of the channel matrix **H**, which results in a unitary matrix **Q** and lower triangular matrix **L** such that $H = LQ, F = Q^{-1}$ and $GL = B$, where G is a diagonal matrix whose elements are the weighting factors at the receivers.

The function of **MOD** shown in Figure 1 is the non-linear modulo operator which is described as follows;

$$f_t(y) = y - \left\lfloor \frac{y + \frac{t}{2}}{t} \right\rfloor xt$$

This modulo function is a mapping from the real numbers R to This modulo function is a mapping from the real numbers R to $\left[\frac{-t}{2}, \frac{t}{2}\right]$ where t is a positive number.

III: EXPERIMENTAL DATA & OBSERVATION TABLE

Simulation environment	MATLAB
No. of transmitter	2
No. of receiver	2
Modulation scheme	QPSK/ 16 QAM
SNR	0 TO 18 dB
Iteration value	1000
Correlation length	2
Precoding Scheme	ZF-THP, MMSE-THP

When comparing the ZF-THP scheme for QPSK and 16 QAM modulation schemes, the values of bit error rate (BER) as in **Table 1.1.**

SNR (in dB)	QPSK (ZF-THP)	16-QAM (ZF-THP)
0	0.2677	0.3878
2	0.2154	0.3428
4	0.1751	0.2969
6	0.1338	0.2557
8	0.0855	0.2002
10	0.06238	0.1598
12	0.04038	0.1212
14	0.02150	0.08563
16	0.0120	0.05525
18	0.0085	0.0355

Table 1.1 Bit Error rate (BER) for ZF-THP for QPSK and 16 QAM

When comparing the MMSE-THP for QPSK with 16 QAm modulation type the observation are as in **Table 1.2**

SNR (in dB)	QPSK (MMSE-THP)	16-QAM (MMSE-THP)
0	0.2109	0.3265
2	0.1726	0.2991
4	0.1383	0.2661
6	0.09725	0.2272
8	0.0657	0.1887
10	0.0455	0.1494
12	0.2738	0.1159
14	0.0140	0.0804
16	0.0093	0.0490
18	0.0053	0.0339

Table 1.2 Bit Error rate (BER) for MMSE-THP for QPSK and 16 QAM

IV: SIMULATION RESULTS

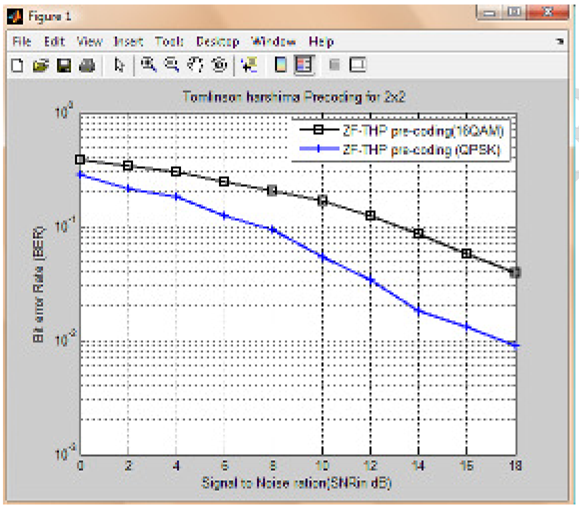

Fig. 1.2 Comparision between ZF-THP with QPSK to ZF-THP with 16 QAM.

From fig. 1.2 we can see that at the SNr value of 18 dB, ZF-THP with QPSK gives BER of 0.0090 and ZF-THP with 16 QAM gives BER of 0.0388 at the same SNR value. This proves that the ZF-THP gives better performance compared to ZF-THP with 16QAM. From fig. 1.3 MMSE-THP provides BER of the 0.0045 at SNR value of 18 dB.

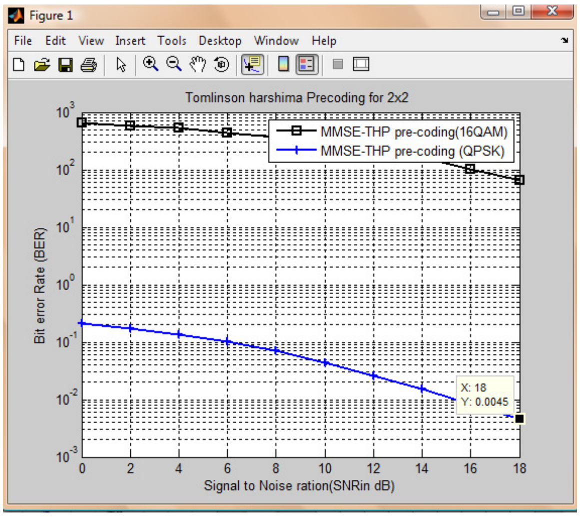

Fig. 1.3 Comparision between ZF-THP with QPSK to ZF-THP with 16 QAM.

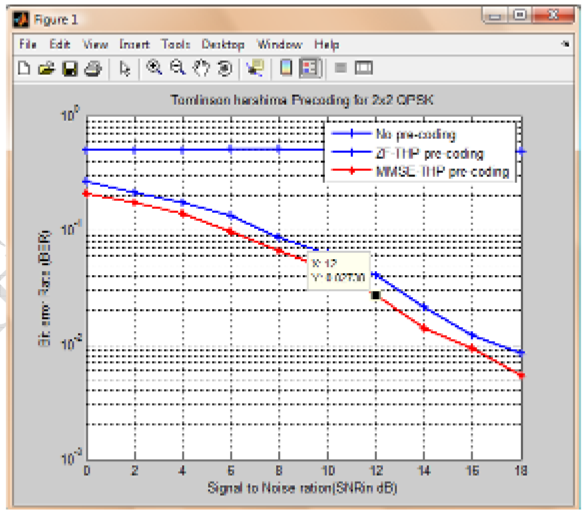

Fig 1.4 Comparision between no precoding, ZF-THP, MMSE-THP for 2x2 QPSK

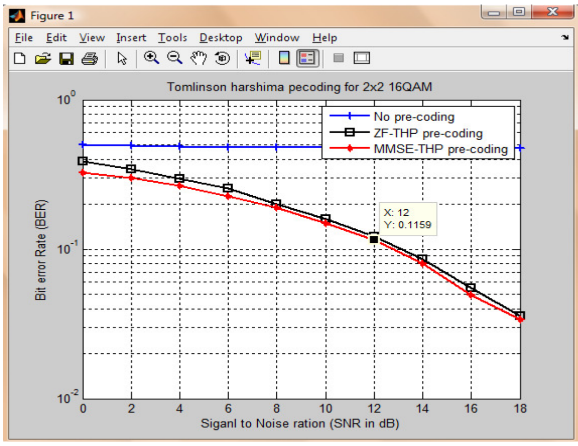

Fig 1.5 Comparision between no precoding, ZF-THP, MMSE-THP for 2x2 16QAM

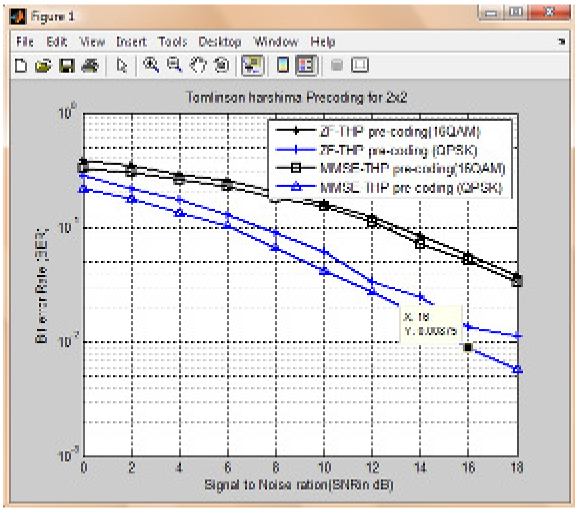

Fig 1.5 Comparision between ZF-THP, MMSE-THP for 2x2 with QPSK and 16QAM.

Comapring all together in a single we can see that MMSE-THP givs the best as compare to ZF-THP (QPSK and 16QAM) and MMSE-THP (16QAM).

V: CONCLUSION

In this paper, a comparative study on the achievable bit error rate by THP algorithm is derived for both ZF and MMSE THP. The introduced equation gives a relation for transmitter, channel matrix and receiver for THP in downlink. Result shows the better performance of the QPSK modulation over 16 QAM for ZF-THP and MMSE-THP. Proven the MMSE-THP having lowest bit error rate (BER) for different SNR values for given parameters in the downlink. A difference of capacity gain of approximately 0.21 dB is been provided by MMSE-THP with QPSK modulation than 16 QAM MMSE-THP.

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