Research Paper

DOWNLINK: PERFORMANCE OF MIMO-CDMA SYSTEM USING NON-LINEAR DETECTOR

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ABSTRACT—

In this correspondence, we present the performance of uncoded multiple-input multiple-output (MIMO) Code division multiple access scheme (CDMA) system for downlink (DL) transmission over correlated frequency-selective channel. In a multi user DL transmission, users experience multi user interference (MUI), multi-path effects and inter antenna interference (IAI) due to the presence of multiple antennas both at the transmitter and receiver. Further, the antenna correlation results in bit error rate(BER) performance degradation. These issues require serious attention in multi-user environment communication system. We consider sub-optimal multi-user detection techniques based on zero-forcing(ZF) maximum -a-posteriori probability(MAP) Multi-user detection(MUD) to mitigate the effects of above mentioned interferences in the context of DL MIMO-CDMA system. Specifically we analyze the effects of three tap delay profile based on SUI channel models in the DL MIMO-CDMA system. Our computer simulation reveals that MIMO-CDMA with the non-linear MUD based on ZF-MAP algorithm is capable of achieving better performance with less signal to noise ratio in terms of achievable BER by mitigating the effects of MUI and multi-path propagations.

KEYWORDS— polarization diversity, SUI channel model, multiple input multiple output (MIMO), multi-user detection (MUD), multi-user interference (MUI), multi stream interference (MSI).

I. INTRODUCTION

Code Division Multiple Access (CDMA) Scheme is a commonly used and recommended accessing scheme for the present and the future wireless communications owing to its features such as it supports many users by making use of orthogonal spreading sequence, alleviation of cross cell interference, mitigation of multi-path fading effect etc., CDMA is working on the principle of Direct Sequence (DS) spectrum techniques and orthogonal spreading sequences which is used to distinguish multi-users signals. It has been represented in various wireless standard such as IS 95 CDMA technology, Universal Mobile Telecommunication Systems (UMTS) and CDMA 2000 .The author in [1] have explicated the performance of Multi-carrier (MC) DS CDMA systems and elucidated that we can achieve better bit-error rate (BER) performance in multi-user interference limited wireless fading channel. The authors Mohamed S. Aljerjawi and Walaa Hamouda in [2] have demonstrated the performance of single carrier multi-user MIMO assisted DS-CDMA system for Rayleigh Fading Channels. It has been addressed in [3] that the performance of Zero-Forcing (ZF) and Minimum Mean-Square Error (MMSE) Multi-user detection (MUD) in MC DS-CDMA systems. The author L.Hanzo and his team[4] have demonstrated the performance of single carrier and MC DS CDMA system. WeiLi and T. Aaron Gulliver in [5] have addressed the concept of Successive Interference Cancellation technique (SIC) for CDMA systems. In [6], the authors have addressed the concept of multi-user transmitter pre-processing (MUTP) assisted MC-CDMA system for cooperative communication. In [7], the authors have demonstrated that MUTP assisted downlink (DL) DS-CDMA system provides better performance in terms of achievable BER.

Future wireless communication system demands for various multimedia services with high-speed communication and hence effective method of transmission techniques are required to utilize the limited bandwidth at the physical and MAC layer. It has been recently demonstrated that the theoretic information capacity of Multiple-input and Multiple-output(MIMO) system has shown enormous potential which increases linearly with number of transmit antennas and receive antennas. Such MIMO system can be realized using Vertical bell laboratories Layered space-time architecture (VBLAST) and Space-time transmit diversity (STTD). VBLAST architecture increases the data rate by transmitting different data stream from different antenna simultaneously and achieves spatial multiplexing.STTD structure spatially encodes the bit stream across all transmit antennas and offers diversity gain . The benefits of MIMO technology which helps to achieve significant performance gains are array gain, spatial diversity gain, spatial multiplexing gain and interference reduction [8][9][10]. MIMO with V-BLAST architecture is to fully exploit the multi path rather mitigating it, by considering the multipath itself as a source of diversity that allows the parallel transmission of sub stream from the user [11].Further in [11] ,the author K.S.Vishvaksenan and his team have demonstrated that both spatial multiplexing and spatial diversity can be obtained using Double space-time transmit diversity(DSTTD) structure.

In most of the above mentioned literature, they have investigated the performance of MIMO system for SDMA system. Hence in this contribution, we consider the performance of MIMO-CDMA using ZF-MAP detection algorithm system for SUI-1 channel model using ZF-MAP algorithm.

The rest of the paper is organized as follows: Section-II describe System configuration. Section-III gives the essence of symbol detection techniques. Section-IV elucidates the performance results and discussion. Finally conclusions are drawn in Section- V.

II. SYSTEM CONFIGURATION

Let us consider K-user downlink communication system in which base station (BS) is having N_t transmit antennas and communicate to the multi-user We assume that each user is having N_r receive antennas.

The figure.1 shows transceiver structure of our considered MIMO-CDMA system.

Let transmitted bits stream from BS containing m bits and is represented as

$$\boldsymbol{u}_k = [\boldsymbol{u}_{k1}, \boldsymbol{u}_{k2}, \ldots, \boldsymbol{u}_{km}]^T, k = 1,2,...,K \quad (1)$$

and is transmitted to the k^{th} user from the base station (BS). The input bit stream is then interleaved to combat burst errors.

Let the interleaved sequence be represented as

$$\boldsymbol{x}_k = [\boldsymbol{x}_{k1}, \boldsymbol{x}_{k2}, \ldots, \boldsymbol{x}_{km}]^T, k = 1,2,...,K \quad (2)$$

Then it is spread by user specific spreading sequence $\boldsymbol{c}_{\mathbf{k}}$ where

$$\boldsymbol{c}_{\mathbf{k}} = \frac{\mathbf{1}}{\sqrt{N_{\mathbf{c}}}} \left[\boldsymbol{c}_{\mathbf{k0}}, \boldsymbol{c}_{\mathbf{k1}}, \ldots, \boldsymbol{c}_{\mathbf{k}\left(N_c - 1\right)} \right]^{\mathbf{T}}, k = 1,2,...,K \quad (3)$$

and N_c represents spreading length. We consider orthogonal spreading sequence

$$\boldsymbol{C}_k = diag\{c_k, c_k, c_k, \ldots, c_k\} = I_m \bullet c_k, k = 1,2,..., K \quad (4)$$

This Time domain spreading code is exploited to obtain the spread sequence of the k^{th} user having length vector $N_c m$ and it's been expressed as

$$\boldsymbol{C}_k \boldsymbol{x}_k, k = 1,2,...,K \quad (5)$$

Then all the user's signals are summed to obtain $\boldsymbol{x}$ where

$$\boldsymbol{z} = \sum_{\boldsymbol{k}=1}^{\boldsymbol{K}} \boldsymbol{d}_{\boldsymbol{k}} \quad (6)$$

Then the bit streams are transmitted by VBLAST architecture.

In this contribution, we assume that channel matrix that connects $\boldsymbol{k}^{\text{th}}$ MS and BS is frequency-selective and is based on Stanford University Interim (SUI)[12] and the channel profiles are detailed in Table-1.

TABLE 1: CHANNEL MODEL PARAMETERS FOR SUI CHANNEL

Path Number	SUI-1	
(l)	Delay (μs)	Power (dB) $\psi(\tau_l)$
1	0	0
2	0.4	-15
3	0.9	-20

Now the impulse response connecting $\boldsymbol{j}^{\text{th}}$ receive antenna and $\boldsymbol{i}^{\text{th}}$ transmit may be defined as

$$\boldsymbol{h}_{ji}(t) = \sum_{l=1}^{L} \boldsymbol{h}_{ji}^{l} \partial(t - \tau_l) \quad (7)$$

where L represents number of paths between $\boldsymbol{j}^{\text{th}}$ receive antenna and $\boldsymbol{i}^{\text{th}}$ transmit as in [8]. The received vector component $\boldsymbol{r}$ at the $\boldsymbol{k}^{\text{th}}$ MS.

Assuming N_r =4 and N_t =4,the received matrix Y at each user is given by

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \\ h_{41} & h_{42} & h_{43} & h_{44} \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix} + \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} \quad (8)$$

Here $N_r \times N_t$ dimensional matrix H is the impulse response of the channel matrix and $N_r \times 1$ dimensional matrix η denotes zero mean circularly symmetric complex Gaussian Noise with covariance $\sigma^2 I_{N_r}$.

$$\boldsymbol{Y} = \boldsymbol{H}_{\boldsymbol{k}} \boldsymbol{Z} + \eta_k \quad (9)$$

where $\boldsymbol{H}_{\boldsymbol{k}}$ is the $N_r \times N_t$ channel matrix

Clearly the above equation can be written as

$$\boldsymbol{Y} = \underbrace{\boldsymbol{H}_k z_k}_{\text{Desired Signal}} + \underbrace{\sum_{i=1, i \neq k}^{K} \boldsymbol{H}_k z_i}_{\text{MAI}} + \eta_k, k = 1,2,..., K \quad (10)$$

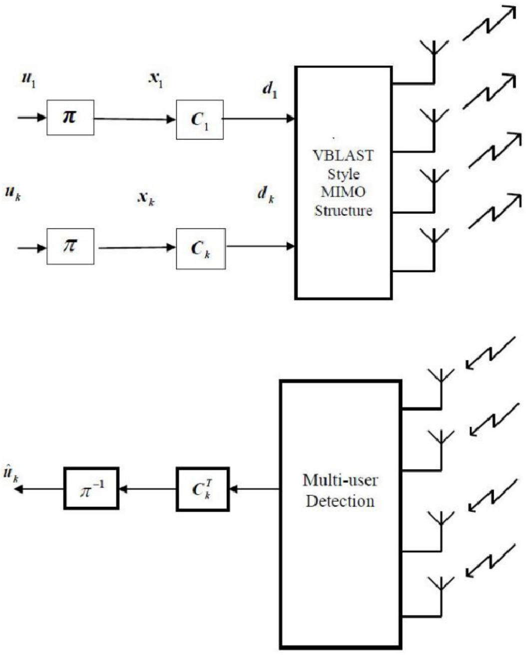

Figure 1 Transceiver architecture of MIMO-CDMA system for downlink transmission

III. SYMBOL DETECTION TECHNIQUE

Initialization

$$i \leftarrow 1$$

$$W_i = H_i^{+} \quad (11)$$

Recursion

$$r_i = W_i y_i \quad (12)$$

$$\boldsymbol{w}_i = \boldsymbol{Q}(\boldsymbol{r}_i) \quad (13)$$

$$\boldsymbol{p}_{ij} = \frac{\boldsymbol{f}_{ij}(\boldsymbol{r}_{ij} / \boldsymbol{w}_{ij})}{\sum_{\boldsymbol{w}' \in \boldsymbol{A}} \boldsymbol{f}_{ij}(\boldsymbol{r}_{ij} / \boldsymbol{w}')}, \boldsymbol{j} \notin \{\boldsymbol{q}_1 \ldots \boldsymbol{q}_j\}, \quad (14)$$

$$q_i = \underset{j \notin \{q_1 \ldots q_{i-1}\}}{\arg\max} \{p_{ij}\} \text{ (Ordering operation)} \quad (15)$$

$$\hat{z}_{q_i} = (\boldsymbol{w}_i)_{q_i} \quad (16)$$

$$\boldsymbol{y}_{i+1} = \boldsymbol{y}_i - \hat{z}_{q_i} (\boldsymbol{H})_{q_i} \text{ (Nulling operation)} \quad (17)$$

$$W_{i+1} = H_{\bar{q}_i}^{H}$$

(Canceling operation) (18)

$$i \leftarrow i + 1$$

Then the bit stream is despread by user specific orthogonal spreading sequence and de-interleaved to obtain $\hat{\boldsymbol{u}}_k$.

IV. PERFORMANCE RESULTS

In this section, we present the performance of MIMO-CDMA system for SUI-1 channel model. We consider the channel models based on SUI specifications. We summarize the simulation parameters in Table 2.

TABLE 2: SIMULATION PARAMETERS

Parameters	Attributes
Modulation Technique	BPSK
Channel Spacing	20 MHz
Sampling frequency	22.5MHz
Number of transmitter antennas	4
Number of receiver antennas	4
Channel model	SUI-1 Channel model

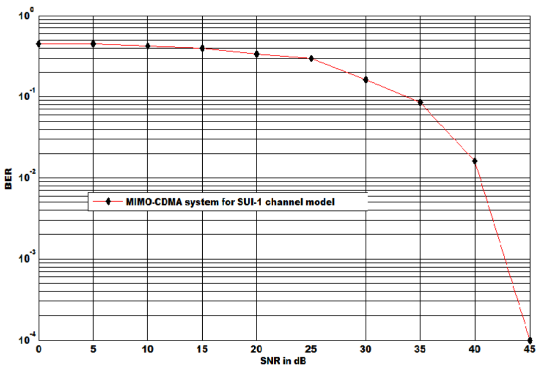

Figure 2 Average Bit error rate (BER) performance MIMO -CDMA with ZF/MAP -OSIC detection for N_r =4 and N_t =4 considering 50 users for SUI-1 channel model.

We consider BPSK modulation. We adopt a Doppler shift of 0.5 Hz with antenna correlation of 0.7 for SUI-1 channel model [12]. Additionally, we consider channel realizations of 10,000 for each value of SNR. Figure 2 explicate the average bit error rate (BER) performance of MIMO-CDMA system for frequency- selective channel based on SUI-1 specifications. It is observed that Uni-Polarized MIMO-CDMA system with ZF detection algorithm achieves BER of 10^{-2} for an SNR of 20 dB.

V. CONCLUSION

In this contribution, we investigated the performance of MIMO-CDMA using ZF-MAP algorithm in the context of frequency -selective channel for the DL communications. Our simulation study shows that MSI and MUI provide irreducible error in the BER performance. Additionally, the spatial correlation between antennas both at the transmitter side and receiver side also degrade the performance of our considered system. We concluded that though realising multiple antennas at the mobile station is not trivial, the gain achieved in terms of spectral efficiency is better than compared to single antenna at the MS, which is an equally if not more complex operation.

REFERENCES

[1] Shiro Kondo and Laurence B. Milstein, “Performance of Multicarrier DS CDMA systems”, *IEEE transaction on Communications.* vol.44, No.2, February 1996, pp. 238-246.

[2] Mohammed S. AlJerjawi and Walaa Hamouda, “Performance Analysis of Multiuser DS-CDMA in MIMO Systems over Rayleigh Fading channels”, *IEEE Transactions on Vehicular Technology.* vol. 57, no. 3, May, 2008, pp. 1480-1493.

[3] Lie-Liang Yang , Li-Chun Wang , “Zero-forcing and minimum mean square error multiuser detection in generalized multicarrier DSCDMA systems for cognitive radio”, *EURASIP Journal on Wireless Communications and Networking*, Issue 2, No. 14 , Jan 2008.

[4] Rong Zhang and Lajos Hanzo, “Iteratively detected Multi-carrier Interleave division Multiple access”, *International conference MICROC0LL’07, BUDAPEST*, Hungary, May, 2007.

[5] Wei Li, T. Aaron Gulliver, “Successive Interference Cancellation for DSCDMA Systems with Transmit Diversity”, *EURASIP Journal on Wireless Communications and Networking*, Issue 1, Pages 46-54, 2004.

[6] Prabagarane Nagaradjane, Sriram Ravichandran, Nithin Srinivasan, Shruthi Ravichandran, Selvam Paranche Damodaran, "Cooperative communication-aided multi-carrier code division Multiple access downlink transmission with transmitter preprocessing: performance results", *IET Communication* ,Vol. 7, no. 17, pp. 1915-1924, 2013.

[7] Nithya Vani Anichetty Murali, Prabagarane Nagaradjane and Selvam Paranche Damodaran, “Performance of relay-aided downlink DS-CDMA system using transmitter preprocessing based on feedback information”, *Elsevier journal on Computers and Electrical Engineering,* vol.40, issue 4, pp.1306-1315, May, 2014.

[8] P.W.Wolniansky,G.J.Foschini,G.D.Golden and R.A.Valenzuela,”V-Blast:An architecture for realizing very high data rate over the rich scattering wireless channel”,IEEE ISSSE,pp.295-300,sep 1998.

[9] L.Zheng and D.N.C.Tse,”Diversity and Multiplexing:a fundamental trade-off in multiple-antenna channels”,IEEE Trans.info.theory,Vol.49,pp.1073-1096,May 2003.

[10] Jinho choi,”Nulling and cancellation detector for MIMO channels and its application to multi stage receiver for coded signals:Performance and optimization”,IEEE Transaction on wireless communication,Vol.5,no.5,May 2006

[11] K.S. Vishvaksenan, R. Seshasayanan and Sudharssun Subramanian, “Performance of Dual-Polarized DSTTD-IDMA system over correlated frequency selective channels”, *Elsevier Journal on Computer and Electrical Engineering,* vol.40, issue 4, pp.1296-1305, May,2014.

[12] Maucher J and Furrer J, Heise , IEEE Std. 2007, IEEE Standard for WIMAX 802.16, Publisher, Hannover,2007