Co-channel Interference Cancellation Based On MIMO Space-Time System

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Abstract— This article deals with the exploitation of multiple input multiple output (MIMO) systems for broadband wireless indoor applications. More specifically, multiple access channels with multiple antennas are considered. Aiming to improve the system performance, an interference cancellation scheme is proposed to eliminate the interference for each user. The decoding complexity is the lowest and the diversity gain is the highest with similar configuration. Computer simulation results show the effectiveness of the interference cancellation scheme based on MIMO systems.

Key Words— *Multiple Input Multiple Output(MIMO), Multiple Access Channel (MAC), Alamouti Codes, Diversity, Decoding, Interference Cancellation***.**

I. Introduction

Research for high-bit-rate data transmission and high-quality information exchange between terminals is becoming one of the new challenging targets in telecommunications research. Multiple input multiple output (MIMO) systems are currently stimulating considerable interest across the wireless industry because they appear to be a key technology for future wireless generations [1]–[9]. An (N,M)-MIMO wireless system can be generally defined as a MIMO system in which N signals are transmitted by N antennas at the same time using the same bandwidth and, thanks to effective processing at the receiver side based on the M received signals by M different antennas, is able to distinguish the different transmitted signals. The processing at the receiver is essentially efficient co-channel interference cancellation on the basis of the collected multiple information. This permits improving system performance whether the interest is to increase the single link data rate or increase the number of users in the whole system.

An enhanced form of MIMO technology that is gaining acceptance is Multi-user MIMO or MU-MIMO. Multi-user MIMO enables multiple independent radio terminals to access a system enhancing the communication capabilities of each individual terminal. MU-MIMO exploits the maximum system capacity by scheduling multiple users to be able to simultaneously access the same channel using the spatial degrees of freedom offered by MIMO. To enable MU-MIMO to be used there are several approaches that can be adopted, and a number of applications/versions that are available. MU-MIMO provides a methodology whereby spatial sharing of channels can be achieved. This can be achieved at the cost of additional hardware - filters and antennas – but the incorporation does not come at the expense of additional bandwidth as is the case when technologies such as FDMA, TDMA or CDMA are used.

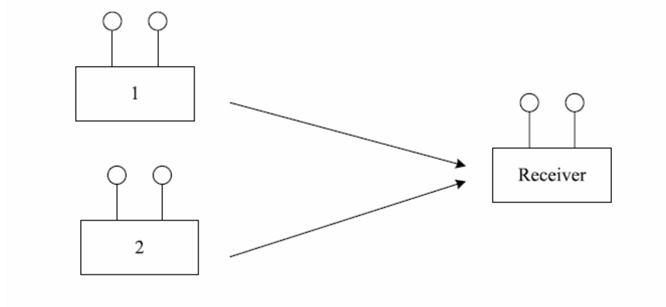

Fig. 1. Channel Model

In this paper, we focus on MIMO multiple access channels [10]–[18]. This form of MU-MIMO is used for a multiple access channel - hence MIMO and it is used in uplink scenarios. For the MIMO-MAC the receiver performs much of the processing - here the receiver needs to know the channel state and uses Channel Sate Information at the Receiver, CSIR. Determining CSIR is generally easier than determining CSIT, but it requires significant levels of uplink capacity to transmit the dedicated pilots from each user. However MIMO MAC systems outperform point-to-point MIMO particularly if the number of receiver antennas is equal to or greater than the number of transmit antennas at each user.

Since each user transmits at the same time, how to deal with the co-channel interference is an interesting question. [19]–[28] discuss the strategies to tackle the co-channel interference when channel knowledge is known at the transmitter. In this paper, we propose and analyze a scheme when channel knowledge is not known at the transmitter, a scenario which is more practical. The article is organized as follows. In the next section the system model is introduced. Detailed interference cancellation procedures are provided and performance analysis is given. Then simulation results are presented. Concluding remarks are given in the final section.

II. Interference Cancellation and Performance Analysis

Assume we have a multiuser wireless communication system where the receiver is equipped with 2 receive antennas. There are 2 transmitters each with 2 transmit antennas. Let $c_{t,n}(j)$ denote the transmitted symbol from the n-th antenna of user j at transmission interval t and $r_{t,m}$ be the received word at the receive antenna m at the receiver. Then, for the received symbols we will have

$$r_{t,m} = \sum_{j=1}^{J}\sum_{n=1}^{N} \alpha_{n,m}(j)c_{t,n}(j) + \eta_{t,m} \quad (1)$$

It is well-known that one can separate signals sent from J different users each equipped with N transmit antennas, with enough receive antennas. We can simply form a decoding matrix that is orthogonal to the space spanned by channel coefficients of the users to be eliminated. For example, if we let

$$R_t = C_t H + N_t \quad (2)$$

where

$$C_t = (C_t(1), C_t(2), \ldots, C_t(J)) \quad (3)$$

$$R_t = (r_{t,1}, r_{t,2}, \ldots, C_{t,M}) \quad (4)$$

$$N_t = (\eta_{t,1}, \eta_{t,2}, \ldots, \eta_{t,M}) \quad (5)$$

$$H = (H(1)^T | H_2^T, \ldots, H(J)^T) \quad (6)$$

with

$$C_t(j) = (c_{t,1}(j), c_{t,2}(j), \ldots, c_{t,N}(j)) \quad (7)$$

and

$$H(j) = \begin{pmatrix} \alpha_{1,1}(j) & \alpha_{1,2}(j) & \cdots & \alpha_{1,M}(j) \\ \alpha_{2,1}(j) & \alpha_{2,2}(j) & \cdots & \alpha_{2,M}(j) \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{N,1}(j) & \alpha_{N,2}(j) & \cdots & \alpha_{N,M}(j) \end{pmatrix} \quad (8)$$

Therefore, one can rewrite Equation (2) as follows:

$$R_t = \sum_{j=1}^{J} C_t(j)H(j) + N_t \quad (9)$$

To decode user 1, one can simply find a zero-forcing(ZF) matrix Z such as

$$H(1)Z \neq 0 \quad (10)$$

and

$$H(j)Z = 0 \quad \text{for} \quad j \neq 1 \quad (11)$$

In other words, Z should null the space spanned by the row vectors of all $H(j)$s, for $j = 2, 3, \ldots, J$. Also, it should not null at least one row vector of $H(1)$. Since all the rows of $H(j)$s might be linearly independent, the dimension of Z, i.e. M, must be at least equal to the number of these rows, or $(J-1)N+1$. Each antenna group (user) can employ a modulation scheme to benefit transmit diversity; as if it is the only group that is sending data.

In order to reduce the number of required receive antennas, we propose a scheme to cancel the interference with less number of receive antennas.

Consider 2 users each transmitting Alamouti code, i.e. Orthogonal Space-Time Block Code (OSTBC)

$$\begin{pmatrix} a_1 & a_2 \\ -a_2^* & a_1^* \end{pmatrix} \quad (12)$$

to a receiver equipped with at least 2 receive antennas. The received signal at the first receive antenna can be written in the following format:

$$\begin{pmatrix} r_{1,1} \\ r_{2,1} \end{pmatrix} = \begin{pmatrix} s_1(1) & s_2(1) \\ -s_2(1)^* & s_1(1)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,1}(1) \\ \alpha_{2,1}(1) \end{pmatrix} + \begin{pmatrix} s_1(2) & s_2(2) \\ -s_2(2)^* & s_1(2)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,1}(2) \\ \alpha_{2,1}(2) \end{pmatrix} + \begin{pmatrix} \eta_{1,1} \\ \eta_{2,1} \end{pmatrix} \quad (13)$$

At the second receive antenna, we have

$$\begin{pmatrix} r_{1,2} \\ r_{2,2} \end{pmatrix} = \begin{pmatrix} s_1(1) & s_2(1) \\ -s_2(1)^* & s_1(1)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,2}(1) \\ \alpha_{2,2}(1) \end{pmatrix} + \begin{pmatrix} s_1(2) & s_2(2) \\ -s_2(2)^* & s_1(2)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,2}(2) \\ \alpha_{2,2}(2) \end{pmatrix} + \begin{pmatrix} \eta_{1,2} \\ \eta_{2,2} \end{pmatrix} \quad (14)$$

The idea behind interference cancellation arises from separate decodability of each symbol; at each receive antenna we perform the decoding algorithm as if there is only one user. This user will be the one the effect of whom we want to cancel out. Then, we simply subtract the soft-decoded value of each symbol in one of the receive antennas from the rest and as a result remove the effect of that user. This procedure is presented in the following. At the first antenna, we have

$$\begin{pmatrix} r_{1,1} \\ r_{2,1}^* \end{pmatrix} = \begin{pmatrix} \alpha_{1,1}(1) & \alpha_{2,1}(1) \\ \alpha_{2,1}(1)^* & -\alpha_{1,1}(1)^* \end{pmatrix} \begin{pmatrix} s_1(1) \\ s_2(1) \end{pmatrix} + \begin{pmatrix} \alpha_{1,1}(2) & \alpha_{2,1}(2) \\ \alpha_{2,1}(2)^* & -\alpha_{1,1}(2)^* \end{pmatrix} \begin{pmatrix} s_1(2) \\ s_2(2) \end{pmatrix} + \begin{pmatrix} \eta_{1,1} \\ \eta_{2,1}^* \end{pmatrix} \quad (15)$$

At the second antenna, we have

$$\begin{pmatrix} r_{1,2} \\ r_{2,2}^* \end{pmatrix} = \begin{pmatrix} \alpha_{1,2}(1) & \alpha_{2,2}(1) \\ \alpha_{2,2}(1)^* & -\alpha_{1,2}(1)^* \end{pmatrix} \begin{pmatrix} s_1(1) \\ s_2(1) \end{pmatrix} + \begin{pmatrix} \alpha_{1,2}(2) & \alpha_{2,2}(2) \\ \alpha_{2,2}(2)^* & -\alpha_{1,2}(2)^* \end{pmatrix} \begin{pmatrix} s_1(2) \\ s_2(2) \end{pmatrix} + \begin{pmatrix} \eta_{1,2} \\ \eta_{2,2}^* \end{pmatrix} \quad (16)$$

In order to cancel the signals s_1^1 and s_2^1 from User 1, we first multiply both sides of Equation (15) with $\begin{pmatrix} \alpha_{1,1}(1) & \alpha_{2,1}(1) \\ \alpha_{2,1}(1)^* & -\alpha_{1,1}(1)^* \end{pmatrix}^\dagger$ and multiply both sides of Equation (16) with $\begin{pmatrix} \alpha_{1,2}(1) & \alpha_{2,2}(1) \\ \alpha_{2,2}(1)^* & -\alpha_{1,2}(1)^* \end{pmatrix}^\dagger$ Then we have Equations (23) and (24) in the next page, where $\eta'_{1,1}$, $\eta'_{2,1}$, $\eta'_{1,2}$, $\eta'_{2,2}$ are given by

$$\begin{pmatrix} \eta'_{1,1} \\ \eta'_{2,1} \end{pmatrix} = \begin{pmatrix} \alpha_{1,1}^*(1) & \alpha_{2,1}(1) \\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1) \end{pmatrix} \begin{pmatrix} \eta_{1,1} \\ \eta_{2,1} \end{pmatrix} \quad (17)$$

$$\begin{pmatrix} \eta'_{1,2} \\ \eta'_{2,2} \end{pmatrix} = \begin{pmatrix} \alpha_{1,2}^*(1) & \alpha_{2,2}(1) \\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1) \end{pmatrix} \begin{pmatrix} \eta_{1,2} \\ \eta_{2,2}^* \end{pmatrix} \quad (18)$$

In order to eliminate the effect of user 1, we need to divide both sides of Equation (23) by

$$\frac{1}{(|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2)} \quad (19)$$

and divide both sides of Equation (24) by

$$\frac{1}{(|\alpha_{1,2}(1)|^2 + |\alpha_{2,2}(1)|^2)} \quad (20)$$

Equations (23) and (24) becomes Equations (25) and (26). Then we can subtract both sides of Equation (25) from Equation (26). The resulting terms are shown by

$$\widehat{y} = \widehat{H}\begin{pmatrix} s_1(2) \\ s_2(2) \end{pmatrix} + \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} \tag{21}$$

where $\widehat{y}$ and $\widehat{H}$ are given by Equations (27) and (28). $\eta''_{1,2}$, $\eta''_{2,2}$ are given by

$$\begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} = \frac{1}{(|\alpha_{1,2}(1)|^2 + |\alpha_{2,2}(1)|^2)}\begin{pmatrix} \eta'_{1,2} \\ \eta'_{2,2} \end{pmatrix} - \frac{1}{(|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2)}\begin{pmatrix} \eta'_{1,1} \\ \eta'_{2,1} \end{pmatrix} \tag{22}$$

The distribution of $\eta''_{1,2}$, $\eta''_{2,2}$ are Gaussian white noise. In Equation (23), $\widehat{H}$ can be written as the following structure:

$$\widehat{H} = \begin{pmatrix} a & b \\ b^* & -a^* \end{pmatrix} \tag{31}$$

where a and b are given by Equations (29) and (30). In order to decode the s_1^2, we can multiply both sides of the Equation (21) with $\begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \widehat{y} = \begin{pmatrix} |a|^2 + |b|^2 & 0 \end{pmatrix}\begin{pmatrix} s_1(2) \\ s_2(2) \end{pmatrix} + \begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} = (|a|^2 + |b|^2)s_1(2) + \begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} \tag{32}$$

In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a|^2 + |b|^2}s_1(2) + \frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} \tag{33}$$

Maximum likelihood decoding can be used to decode s_1^2:

$$\widehat{s}_1^2 = \arg\min_{s_1^2} \left| \frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} a \\ b^* \end{pmatrix}^\dagger \widehat{y} - \sqrt{|a|^2 + |b|^2}s_1(2) \right|_F^2 \tag{34}$$

So the decoding is symbol-by-symbol. In order to decode the s_2^2, we can multiply both sides of the Equation (21) with $\begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \widehat{y} = \begin{pmatrix} 0 & |a|^2 + |b|^2 \end{pmatrix}\begin{pmatrix} s_1(2) \\ s_2(2) \end{pmatrix} + \begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} = (|a|^2 + |b|^2)s_2(2) + \begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} \tag{35}$$

In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a|^2 + |b|^2}s_2(2) + \frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,2} \\ \eta''_{2,2} \end{pmatrix} \tag{36}$$

Maximum likelihood decoding can be used to decode s_2^2:

$$\widehat{s}_2^2 = \arg\min_{s_2^2} \left| \frac{1}{\sqrt{|a|^2 + |b|^2}}\begin{pmatrix} b \\ -a^* \end{pmatrix}^\dagger \widehat{y} - \sqrt{|a|^2 + |b|^2}s_2(2) \right|_F^2 \tag{37}$$

The decoding is also symbol-by-symbol. Now we analyze the diversity. From Equation (32), we know that the diversity is determined by factor $\sqrt{|a|^2 + |b|^2}$. The diversity is defined as

$$d = -\lim_{\rho \to \infty} \frac{\log P_e}{\log \rho} \tag{38}$$

where ρ denotes the SNR and P_e represents the probability of error. It is known that the error probability can be written as

$$\begin{aligned} &P(s_1(2) \to error|a, b) \\ &= Q\left(\sqrt{\frac{\rho|\sqrt{|a|^2 + |b|^2}\mathbf{e}|_F^2}{4}}\right) \\ &\le \exp\left(-\frac{\rho(|a|^2 + |b|^2)\mathbf{e}^\dagger\mathbf{e}}{4}\right) \\ &= \exp\left(-\frac{\rho(|a|^2 + |b|^2)e^2}{4}\right) \end{aligned} \tag{39}$$

where e is the error. We need to analyze a and b. Conditioned on $\alpha_{1,2}(1), \alpha_{2,2}(1), \alpha_{1,1}(1), \alpha_{2,1}(1)$, then a and b are both Gaussian random variables. It is easy to verify that

$$E[a \cdot b|\alpha_{1,2}(1), \alpha_{2,2}(1), \alpha_{1,1}(1), \alpha_{2,1}(1)] = 0 \tag{40}$$

So a and b are independent Gaussian random variables. We have

$$\begin{aligned} &P(s_1(2) \to error) \\ &= E[E[P(s_1(2) \to error|a, b)]| \\ &\qquad \alpha_{1,2}(1), \alpha_{2,2}(1), \alpha_{1,1}(1), \alpha_{2,1}(1)] \\ &\le E[E[\exp\left(-\frac{\rho(|a|^2 + |b|^2)e^2}{4}\right)\Big| \\ &\qquad \alpha_{1,2}(1), \alpha_{2,2}(1), \alpha_{1,1}(1), \alpha_{2,1}(1)]] \\ &= E[\frac{1}{\prod_{j=1}^2[1 + \frac{\rho e^2}{4})]}| \\ &\qquad \alpha_{1,2}(1), \alpha_{2,2}(1), \alpha_{1,1}(1), \alpha_{2,1}(1)] \\ &= \frac{1}{\prod_{j=1}^2[1 + \frac{\rho e^2}{4})]} \end{aligned} \tag{41}$$

When ρ is large, Equation (41) becomes

$$P(s_1(2) \to error) \le \rho^{-2}\left(\frac{e^2}{4}\right)^{-2} \tag{42}$$

By Equation (38), the diversity is 2. Now we analyze the diversity for $s_2(2)$. We know that the diversity is determined

$$\begin{pmatrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}r_{1,1}\\ r_{2,1}^*\end{pmatrix} = (|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2)\begin{pmatrix}s_1^1\\ s_2^1\end{pmatrix} + \begin{pmatrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,1}(2) & \alpha_{2,1}(2)\\ \alpha_{2,1}^*(2) & -\alpha_{1,1}^*(2)\end{pmatrix}\begin{pmatrix}s_1(2)\\ s_2(2)\end{pmatrix} + \begin{pmatrix}\eta_{1,1}'\\ \eta_{2,1}'\end{pmatrix} \quad (23)$$

$$\begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}r_{1,2}\\ r_{2,2}^*\end{pmatrix} = (|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2)\begin{pmatrix}s_1^1\\ s_2^1\end{pmatrix} + \begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,2}(2) & \alpha_{2,2}(2)\\ \alpha_{2,2}^*(2) & -\alpha_{1,2}^*(2)\end{pmatrix}\begin{pmatrix}s_1(2)\\ s_2(2)\end{pmatrix} + \begin{pmatrix}\eta_{1,2}'\\ \eta_{2,2}'\end{pmatrix} \quad (24)$$

$$\frac{1}{(|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2)}\begin{pmatrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}r_{1,1}\\ r_{2,1}^*\end{pmatrix} = \begin{pmatrix}s_1^1\\ s_2^1\end{pmatrix} + \frac{1}{(|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2)}\begin{pmatrix}\eta_{1,1}'\\ \eta_{2,1}'\end{pmatrix} + \left(\frac{1}{(|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2)}\begin{matrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{matrix}\right)\begin{pmatrix}\alpha_{1,1}(2) & \alpha_{2,1}(2)\\ \alpha_{2,1}^*(2) & -\alpha_{1,1}^*(2)\end{pmatrix}\begin{pmatrix}s_1(2)\\ s_2(2)\end{pmatrix} \quad (25)$$

$$\frac{1}{(|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2)}\begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}r_{1,2}\\ r_{2,2}^*\end{pmatrix} = \begin{pmatrix}s_1^1\\ s_2^1\end{pmatrix} + \frac{1}{(|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2)}\begin{pmatrix}\eta_{1,2}'\\ \eta_{2,2}'\end{pmatrix} + \frac{1}{(|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2)}\begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,2}(2) & \alpha_{2,2}(2)\\ \alpha_{2,2}^*(2) & -\alpha_{1,2}^*(2)\end{pmatrix}\begin{pmatrix}s_1(2)\\ s_2(2)\end{pmatrix} \quad (26)$$

$$\widehat{y} = \frac{1}{|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2}\begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}r_{1,2}\\ r_{2,2}^*\end{pmatrix} - \frac{1}{|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2}\begin{pmatrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}r_{1,1}\\ r_{2,1}^*\end{pmatrix} \quad (27)$$

$$\widehat{H} = \left[\frac{1}{|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2}\begin{pmatrix}\alpha_{1,2}^*(1) & \alpha_{2,2}(1)\\ \alpha_{2,2}^*(1) & -\alpha_{1,2}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,2}(2) & \alpha_{2,2}(2)\\ \alpha_{2,2}^*(2) & -\alpha_{1,2}^*(2)\end{pmatrix} - \frac{1}{|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2}\begin{pmatrix}\alpha_{1,1}^*(1) & \alpha_{2,1}(1)\\ \alpha_{2,1}^*(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,1}(2) & \alpha_{2,1}(2)\\ \alpha_{2,1}^*(2) & -\alpha_{1,1}^*(2)\end{pmatrix}\right] \quad (28)$$

$$a = \frac{1}{|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2}[\alpha_{1,2}^*(1)\alpha_{1,2}(2)+\alpha_{2,2}(1)\alpha_{2,2}^*(2)] - \frac{1}{|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2}[\alpha_{1,1}^*(1)\alpha_{1,1}(2)+\alpha_{2,1}(1)\alpha_{2,1}^*(2)] \quad (29)$$

$$b = \frac{1}{|\alpha_{1,2}(1)|^2+|\alpha_{2,2}(1)|^2}[\alpha_{1,2}^*(1)\alpha_{2,2}(2)-\alpha_{2,2}(1)\alpha_{1,2}^*(2)] - \frac{1}{|\alpha_{1,1}(1)|^2+|\alpha_{2,1}(1)|^2}[\alpha_{1,1}^*(1)\alpha_{2,1}(2)-\alpha_{2,1}(1)\alpha_{1,1}^*(2)] \quad (30)$$

by factor $\sqrt{|a|^2+|b|^2}$. The error probability can be written as

$$\begin{aligned} & P(s_2(2)\to error|a,b)\\ &= Q\left(\sqrt{\frac{\rho|\sqrt{|a|^2+|b|^2}\mathbf{e}|_F^2}{4}}\right)\\ &\le \exp\left(-\frac{\rho(|a|^2+|b|^2)\mathbf{e}^\dagger\mathbf{e}}{4}\right)\\ &= \exp\left(-\frac{\rho(|a|^2+|b|^2)e^2}{4}\right) \end{aligned} \quad (43)$$

where e is the error. We need to analyze a and b. Conditioned on $\alpha_{1,2}(2),\alpha_{2,2}(2),\alpha_{1,1}(2),\alpha_{2,1}(2)$, then a and b are both Gaussian random variables. It is easy to verify that

$$E[a\cdot b|\alpha_{1,2}(2),\alpha_{2,2}(2),\alpha_{1,1}(2),\alpha_{2,1}(2)] = 0 \quad (44)$$

So a and b are independent Gaussian random variables. We have

$$\begin{aligned} & P(s_2(2)\to error)\\ &= E[E[P(s_2(2)\to error|a,b)]|\\ &\qquad \alpha_{1,2}(2),\alpha_{2,2}(2),\alpha_{1,1}(2),\alpha_{2,1}(2)]\\ &\le E[E[\exp\left(-\frac{\rho(|a|^2+|b|^2)e^2}{4}\right)\Bigg|\\ &\qquad \alpha_{1,2}(2),\alpha_{2,2}(2),\alpha_{1,1}(2),\alpha_{2,1}(2)]]\\ &= E[\frac{1}{\prod_{j=1}^2[1+\frac{\rho e^2}{4})]}|\\ &\qquad \alpha_{1,2}(2),\alpha_{2,2}(2),\alpha_{1,1}(2),\alpha_{2,1}(2)]\\ &= \frac{1}{\prod_{j=1}^2[1+\frac{\rho e^2}{4})]} \end{aligned} \quad (45)$$

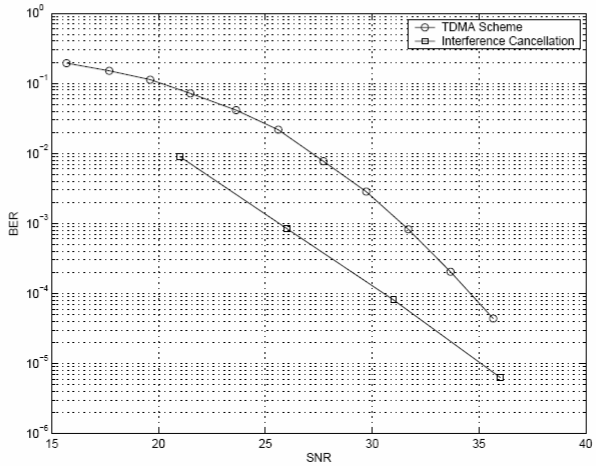

Fig. 2. 8-PSK constellation with interference cancellation

When ρ is large, Equation (45) becomes

$$P(s_2(2) \rightarrow error) \leq \rho^{-2} \left(\frac{e^2}{4}\right)^{-2} \tag{46}$$

By Equation (38), the diversity for s_2^2 is 2.

In summary, the interference cancellation based on Alamouti codes can achieve cancel the interference successfully and the decoding complexity is symbol-by-symbol which is the lowest and the diversity is 2, which is the best as far as we know when no channel information is available at the user side and the lowest decoding complexity is required.

III. Simulations

In order to evaluate the proposed scheme, we use a system with two users with two antennas and one receiver with two receive antennas. This is a typical multiple access channel. The two users are sending signals to the receiver simultaneously. We assume alamouti codes are transmitted. So there will be co-channel interference. If the proposed interference cancellation is used, the performance is provided in Figures 2 where 8-PSK is used. In the figure, we compare the interference cancellation scheme with a TDMA scheme with beamforming scheme. That is, during each time slot, one user transmits while the other keeps silent. In order to make the rate the same for the two schemes, in Figure 2, 64-QAM is used. It is obvious that the proposed scheme has better performance which confirms the effectiveness of the interference cancellation scheme.

IV. Conclusions

In this paper, interference cancellation for multiple access channel is discussed. Only the receiver knows the channel information while the users know nothing. In this case, the proposed scheme can cancel the interference successfully. The decoding complexity is the lowest, while the diversity is the best when low-decoding complexity is required. Detailed decoding procedures are provided and diversity analysis is given for the first time for such a system. The interference cancellation method can be used in many practical systems to enhance the performance.

References

[1] C. Y. Chi and C. H. Chen, “Cumulant-based inverse filter criteria for MIMO blind deconvolution: properties, algorithms, and application to DS/CDMA systems in multipath,” *IEEE Transactions on Signal Processing*, vol 49, no. pp. 1282-1299, 2001.

[2] F. Li, Q. T. Zhang, and S. H. Song, “Efficient optimization of input covariance matrix for MISO in correlated Rayleigh fading,” in *Proceedings of IEEE Wireless Communications and Networking Conference*, March 2007.

[3] W. Y. Ge, J. S. Zhang and G. L. Xue, “MIMO-Pipe Modeling and Scheduling for Efficient Interference Management in Multihop MIMO Networks,” *IEEE Transactions on Vehicular Technology*, vol. 59, no. 8, pp. 3966-3978, 2010.

[4] C. F. Ball, R. Mullner, J. Lienhart, H. Winkler, “Performance analysis of Closed and Open loop MIMO in LTE,” *European Wireless Conference*, pp. 260-265, 2009.

[5] F. Li, *Multi-Antenna Multi-User Interference Cancellation and Detection Using Precoders*, PhD thesis, UC Irvine, 2012

[6] H. Futaki, T. Ohtsuki, “Low-density parity-check (LDPC) coded MIMO systems with iterative turbo decoding,” *Vehicular Technology Conference*, pp 342-346, 2003.

[7] F. Li and H. Jafarkhani, “Multiple-antenna interference cancellation and detection for two users using precoders,” *IEEE Journal of Selected Topics in Signal Processing*, December 2009.

[8] A. Goldsmith, S. Jafar, N. Jindal, S. Vishwanath, “ Capacity limits of MIMO channels,” *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 5, pp. 684-702, 2003.

[9] K. Kusume, G. Dietl, T. Abe, H. Taoka, S. Nagata, “System Level Performance of Downlink MU-MIMO Transmission for 3GPP LTEAdvanced,” *Vehicular Technology Conference*, 2010.

[10] F. Li and H. Jafarkhani, “Interference Cancellation and Detection for More than Two Users,” *IEEE Transactions on Communications*, March 2011.

[11] F. Li and H. Jafarkhani, “Multiple-antenna interference cancellation and detection for two users using quantized feedback,” *IEEE Transactions on Wireless Communication*, vol. 10, no. 1, pp. 154-163, Jan 2011.

[12] E. M. Mohamed, D. Kinoshita, K. Mitsunaga, Y. Higa, H. Furukawa, “MIMO based wireless backhaul,” *Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, 2010.

[13] V. P. Telang, M. A. Herro, “Error control coding for the N-user mod-2 multiple-access channel,” *IEEE Transactions on Information Theory*, vol. 44 , no. 4, pp. 1632-1642, 1998.

[14] F. Li and H. Jafarkhani, “Using quantized feedback to cancel interference in multiple access channels,” in *Proceedings of IEEE Global Telecommunications Conference (Globecom 2010)*, December, 2010.

[15] J. Xiao, Z. Luo, “Multiterminal SourceCChannel Communication Over an Orthogonal Multiple-Access Channel,” *IEEE Transactions on Information Theory*, vol. 53, no. 9, pp 3255-3264, 2007.

[16] M. Griot, A. Casado., “Trellis Codes with Low Ones Density for the OR Multiple Access Channel,” *IEEE International Symposium on Information Theory*, 2006.

[17] A. Nordio, G. Taricco, “Linear receivers for the multiple-input multipl output multiple-access channel,” *IEEE Transactions on Communications*, vol. 54, no. 8, pp 1446-1456, 2006.

[18] F. Li and H. Jafarkhani, “Resource allocation algorithms with reduced complexity in MIMO multi-hop fading channels,” in *Proceedings of IEEE Wireless Communications and Networking Conference*, 2009.

[19] F. Li and Q. T. Zhang, “Transmission strategy for MIMO correlated rayleigh fading channels with mutual coupling,” in *Proceedings of IEEE International Conference on Communications (ICC 2007)*, June, 2007.

[20] B. Nazer, M. Gastpar, “Computation Over Multiple-Access Channels,” *IEEE Transactions on Information Theory*, vol. 53, no. 10, pp. 3498-3516, 2007.

[21] F. Li and H. Jafarkhani, “Interference Cancellation and Detection Using Precoders,” *IEEE International Conference on Communications (ICC 2009)*, June 2009.

[22] U. Basher, A. Shirazi, H. Permuter, “Capacity region of finite state multiple-access channel with delayed state information,” *48th Annual Allerton Conference on Communication, Control, and Computing*, 2010.

[23] N. Prasad, G. Yue, X. Wang, M. Varanasi, “Optimal Successive Group Decoders for MIMO Multiple-Access Channels”, *IEEE Transactions on Information Theory*, vol. 54, no. 11, pp. 4821-4846, 2008.

[24] K. Huang, J. G. Andrews, and R. W. Heath, Jr., “Performance of Orthogonal Beamforming for SDMA with Limited Feedback,” *IEEE Trans. on Veh. Tech.*, vol. 57, no. 5, pp. 1959-1975, May 2009.

[25] F. Li and H. Jafarkhani, “Interference Cancellation and Detection for Multiple Access Channels with Four Users,” *IEEE International Conference on Communications (ICC 2010)*, May 2010.

[26] K. Huang, R. W. Heath, Jr., and J. G. Andrews, “Uplink SDMA with Limited Feedback: Throughput Scaling,” *EURASIP Journal on Advances in Signal Processing, special issue on Limited Feedback*, vol. 2008, Article ID 479357, 2008.

[27] F. Li and H. Jafarkhani, “Space-Time Processing for X Channels Using Precoders,” *IEEE Transactions on Signal Processing*.

[28] K. Huang, R. W. Heath, Jr., and J. G. Andrews, “Space Division Multiple Access with a Sum Feedback Rate Constraint,” *IEEE Trans. on Signal Processing*, vol. 55, no. 7, pp. 3879-3891, July 2007.