Interference Processing for Multi-User Wireless System

Dennis Jenkins, Aaron Falconer and Ethan Hill

***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. In this paper, we derive a scheme that could be used for any number of users with any number of antennas. 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.

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

I. Introduction

Multiple-input multiple-output (MIMO) communication architecture has recently emerged as a new paradigm for wireless communications in rich multipath environment. Using multi element antenna arrays (MEA) at both transmitter and receiver, which effectively exploits the third (spatial) dimension in addition to time and frequency dimensions, this architecture achieves channel capacity far beyond that of traditional techniques. In independent Rayleigh channels the MIMO capacity scales linearly as the number of antennas under some conditions. However, some impairments of the radio propagation channel may lead to a substantial degradation in MIMO performance. Some limitations on the MIMO capacity are imposed by the number of multipath components [1]–[7].

When using spatial multiplexing, MU-MIMO, the interference between the different users on the same channel is accommodated by the use of additional antennas, and additional processing when enables the spatial separation of the different users. There are two scenarios associated with MU-MIMO or Multi-user MIMO: Uplink - Multiple Access Channel and Downlink - Broadcast Channel or BC. The MU-MIMO Multi-User MIMO has the following advantages: Multi-user MIMO offers some significant advantages over other techniques: MU-MIMO systems enable a level of direct gain to be obtained in a multiple access capacity arising from the multi-user multiplexing schemes. This is proportional to the number of base station antennas employed. MU-MIMO appears to be affected less by some propagation issues that affect single user MIMO systems. These include channel rank loss and antenna correlation - although channel correlation still affects diversity on a per user basis, it is not a major issue for multi-user diversity. MU-MIMO allows spatial multiplexing gain to be achieved at the base station without the need for multiple antennas at the UE. This allows for the production of cheap remote terminals - the intelligence and cost is included within the base station. The advantages of using multi-user MIMO, MU-MIMO come at a cost of additional hardware - antennas and processing - and also obtaining the channel state information which requires the use of the available bandwidth.

In this paper, we focus on MIMO multiple access channels [8]–[14]. 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. [15]– [30] 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. Simulation results are presented. Concluding remarks are given in final section.

II. Interference Cancellation and Analysis

Assume that we have a multiuser wireless communication system where the receiver is equipped with J receive antennas There are J transmitters each with 2 transmit antennas. Le $c_{t,n}(j)$ denote the transmitted symbol from the n-th antenna of user j at

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transmission interval t and $r_{t,m}$ be the received code word at the receive antenna m at the receiver. Then, for the

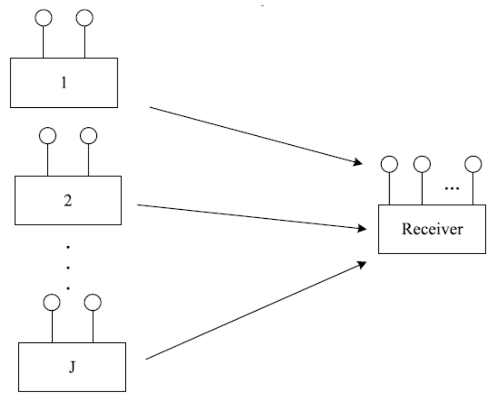

Fig. 1. Channel Model

received symbols we will have

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

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

$$R_t = C_t H + N_t \tag{2}$$

$$H(j) = \begin{pmatrix} \alpha_{1,1}(j) & \alpha_{1,2}(j) & \cdots & \alpha_{1,M}(j) \\ \alpha_{2,1}(j) & \alpha_{2,2}(j) & \cdots & \alpha_{2,M}(j) \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{N,1}(j) & \alpha_{N,2}(j) & \cdots & \alpha_{N,M}(j) \end{pmatrix} \tag{3}$$

where j denotes the jth user. Therefore, one can rewrite Equation (2) as follows:

$$R_t = \sum_{j=1}^{J} C_t(j) H(j) + N_t \tag{4}$$

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

$$H(1)Z \neq 0 \tag{5}$$

and

$$H(j)Z = 0 \quad \text{for} \quad j \neq 1 \tag{6}$$

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

$$\begin{pmatrix} a_1 & a_2 \\ -a_2^* & a_1^* \end{pmatrix} \tag{7}$$

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

$$\begin{pmatrix} r_{1,i} \\ r_{2,i} \end{pmatrix} = \sum_{j=1}^{J} \begin{pmatrix} s_1(j) & s_2(j) \\ -s_2(j)^* & s_1(j)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,i}(j) \\ \alpha_{2,i}(j) \end{pmatrix} + \begin{pmatrix} \eta_{1,i} \\ \eta_{2,i} \end{pmatrix} \tag{8}$$

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 ith antenna, we have

$$\begin{pmatrix} r_{1,i} \\ r_{2,i}^* \end{pmatrix} = \sum_{j=1}^{J} \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}(j)^* & -\alpha_{1,i}(j)^* \end{pmatrix} \begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} + \begin{pmatrix} \eta_{1,i} \\ \eta_{2,i}^* \end{pmatrix} \tag{9}$$

In order to cancel the signals s_1 and s_2 from User 1, we first multiply both sides of Equation (9) with $\begin{pmatrix} \alpha_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha_{2,i}(1)^* & -\alpha_{1,i}(1)^* \end{pmatrix}^\dagger$. Then we have Equations (10):

$$\begin{aligned} &\begin{pmatrix} \alpha_{1,i}^*(1) & \alpha_{2,i}(1) \\ \alpha_{2,i}^*(1) & -\alpha_{1,i}(1) \end{pmatrix} \begin{pmatrix} r_{1,i} \\ r_{2,i}^* \end{pmatrix} \\ &= (|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2) \begin{pmatrix} s_1^1 \\ s_2^1 \end{pmatrix} + \\ &\begin{pmatrix} \alpha_{1,i}^*(1) & \alpha_{2,i}(1) \\ \alpha_{2,i}^*(1) & -\alpha_{1,i}(1) \end{pmatrix} \sum_{j=2}^{J} \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}^*(j) & -\alpha_{1,i}^*(j) \end{pmatrix} \begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} \\ &+ \begin{pmatrix} \eta_{1,i}' \\ \eta_{2,i}' \end{pmatrix} \end{aligned} \tag{10}$$

where $\eta'_{1,i}$, $\eta'_{2,i}$ are given by

$$\begin{pmatrix} \eta'_{1,i} \\ \eta'_{2,i} \end{pmatrix} = \begin{pmatrix} \alpha^*_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1) \end{pmatrix} \begin{pmatrix} \eta_{1,i} \\ \eta_{2,i} \end{pmatrix} \tag{11}$$

In order to eliminate the effect of user 1, we need to divide both sides of Equation (10) by

$$\frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \tag{12}$$

Equations (10) becomes Equations (13):

$$\begin{aligned} &\frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \begin{pmatrix} \alpha^*_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1) \end{pmatrix} \begin{pmatrix} r_{1,i} \\ r^*_{2,i} \end{pmatrix} \\ &= \begin{pmatrix} s^1_1 \\ s^1_2 \end{pmatrix} + \frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \begin{pmatrix} \eta'_{1,i} \\ \eta'_{2,i} \end{pmatrix} \\ &+ \sum_{j=2}^{J} \frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \begin{pmatrix} \alpha^*_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1) \end{pmatrix} \\ &\times \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha^*_{2,i}(j) & -\alpha^*_{1,i}(j) \end{pmatrix} \begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} \end{aligned} \tag{13}$$

Then we can subtract both sides of Equation (13) from the equation when $i = 1$. The resulting terms are shown by

$$\widehat{y}(i) = \sum_{j=2}^{J} \widehat{H}(i) \begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} + \begin{pmatrix} \eta''_{1,i} \\ \eta''_{2,i} \end{pmatrix} \tag{14}$$

where $\widehat{y}(i)$ and $\widehat{H}(i)$, $i = 2, \ldots, J$, are given by Equations (15) and (16):

$$\begin{aligned} &\widehat{y}(i) = \\ &\frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2} \begin{pmatrix} \alpha^*_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1) \end{pmatrix} \begin{pmatrix} r_{1,i} \\ r^*_{2,i} \end{pmatrix} \\ &- \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2} \begin{pmatrix} \alpha^*_{1,1}(1) & \alpha_{2,1}(1) \\ \alpha^*_{2,1}(1) & -\alpha_{1,1}(1) \end{pmatrix} \begin{pmatrix} r_{1,1} \\ r^*_{2,1} \end{pmatrix} \end{aligned} \tag{15}$$

$$\begin{aligned} &\widehat{H}(i) = \\ &\frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2} \begin{pmatrix} \alpha^*_{1,i}(1) & \alpha_{2,i}(1) \\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1) \end{pmatrix} \\ &\qquad \times \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha^*_{2,i}(j) & -\alpha^*_{1,i}(j) \end{pmatrix} \\ &- \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2} \begin{pmatrix} \alpha^*_{1,1}(1) & \alpha_{2,1}(1) \\ \alpha^*_{2,1}(1) & -\alpha_{1,1}(1) \end{pmatrix} \\ &\qquad \begin{pmatrix} \alpha_{1,1}(j) & \alpha_{2,1}(j) \\ \alpha^*_{2,1}(j) & -\alpha^*_{1,1}(j) \end{pmatrix} \end{aligned} \tag{16}$$

$\eta''_{1,i}$, $\eta''_{2,i}$ are given by

$$\begin{aligned} \begin{pmatrix} \eta''_{1,i} \\ \eta''_{2,i} \end{pmatrix} &= \frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \begin{pmatrix} \eta'_{1,i} \\ \eta'_{2,i} \end{pmatrix} \\ &- \frac{1}{(|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2)} \begin{pmatrix} \eta'_{1,1} \\ \eta'_{2,1} \end{pmatrix} \end{aligned} \tag{17}$$

The distribution of $\eta''_{1,i}$, $\eta''_{2,i}$ are Gaussian white noise. In Equation (16), $\widehat{H}(i)$ can be written as the following structure:

$$\widehat{H}(i) = \begin{pmatrix} a(i) & b(i) \\ b(i)^* & -a(i)^* \end{pmatrix} \tag{18}$$

where $a(i)$ and $b(i)$ are given by Equations (19) and (20):

$$\begin{aligned} &a(i) = \\ &\frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2} [\alpha^*_{1,i}(1)\alpha_{1,i}(j) + \alpha_{2,i}(1)\alpha^*_{2,i}(j)] \\ &- \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2} [\alpha^*_{1,1}(1)\alpha_{1,1}(j) + \alpha_{2,1}(1)\alpha^*_{2,1}(j)] \end{aligned} \tag{19}$$

$$\begin{aligned} &b(i) = \\ &\frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2} [\alpha^*_{1,i}(1)\alpha_{2,i}(j) - \alpha_{2,i}(1)\alpha^*_{1,i}(j)] \\ &- \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2} [\alpha^*_{1,1}(1)\alpha_{2,1}(j) - \alpha_{2,1}(1)\alpha^*_{1,1}(j)] \end{aligned} \tag{20}$$

Till now, we have already cancelled the signals from User 1. Follow the same procedure, we can cancel the signals from User 2 to User $J-1$. Finally, we can get the signals from User J only as shown below:

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

In order to decode the $s_1(J)$, we can multiply both sides of the Equation (21) with $\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y}(J) = \begin{pmatrix} |a(J)|^2 + |b(J)|^2 & 0 \end{pmatrix} \begin{pmatrix} s_1(J) \\ s_2(J) \end{pmatrix} + \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix}$$
$$= (|a(J)|^2 + |b(J)|^2) s_1(J) + \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (22)$$

In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a(J)|^2 + |b(J)|^2} s_1(J) + \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (23)$$

Maximum likelihood decoding can be used to decode $s_1(J)$:

$$\widehat{s}_1(J) = \arg\min_{s_1(J)} \left| \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y}(J) - \sqrt{|a(J)|^2 + |b(J)|^2} s_1(J) \right|_F^2 \quad (24)$$

So the decoding is symbol-by-symbol. In order to decode the $s_2(J)$, we can multiply both sides of the Equation (14) with $\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y}(J) = \begin{pmatrix} 0 & |a(J)|^2 + |b(J)|^2 \end{pmatrix} \begin{pmatrix} s_1(J) \\ s_2(J) \end{pmatrix} + \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix}$$
$$= (|a(J)|^2 + |b(J)|^2) s_2(J) + \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (25)$$

In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a(J)|^2 + |b(J)|^2} s_2(J) + \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (26)$$

Maximum likelihood decoding can be used to decode $s_2(J)$:

$$\widehat{s}_2(J) = \arg\min_{s_2(J)} \left| \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}} \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y}(J) - \sqrt{|a(J)|^2 + |b(J)|^2} s_2(J) \right|_F^2 \quad (27)$$

The decoding is also symbol-by-symbol. Now we analyze the diversity. From Equation (22), we know that the diversity is determined by factor $\sqrt{|a(J)|^2 + |b(J)|^2}$. The diversity is defined as

$$d = -\lim_{\rho \to \infty} \frac{\log P_e}{\log \rho} \quad (28)$$

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

$$\begin{aligned} & P(s_1(2) \to error|a, b) \\ & = Q\left(\sqrt{\frac{\rho|\sqrt{|a(J)|^2 + |b(J)|^2}\mathbf{e}|_F^2}{4}}\right) \\ & \le \exp\left(-\frac{\rho(|a(J)|^2 + |b(J)|^2)\mathbf{e}^\dagger \mathbf{e}}{4}\right) \\ & = \exp\left(-\frac{\rho(|a(J)|^2 + |b(J)|^2)e^2}{4}\right) \end{aligned} \quad (29)$$

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

$$E[a(J) \cdot b(J) | \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] = 0 \quad (30)$$

So $a(J)$ and $b(J)$ are independent Gaussian random variables. We have

$$\begin{aligned} & P(s_1(2) \to error) \\ & = E[E[P(s_1(2) \to error|a(J), b(J))]| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] \\ & \le E[E[\exp\left(-\frac{\rho(|a(J)|^2 + |b(J)|^2)e^2}{4}\right)\Bigg| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)]] \\ & = E[\frac{1}{\prod_{j=1}^2 [1 + \frac{\rho e^2}{4})]}| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] \\ & = \frac{1}{\prod_{j=1}^2 [1 + \frac{\rho e^2}{4})]} \end{aligned} \quad (31)$$

When ρ is large, Equation (31) becomes

$$P(s_1(2) \to error) \le \rho^{-2} \left(\frac{e^2}{4}\right)^{-2} \quad (32)$$

By Equation (28), the diversity is 2. Now we analyze the diversity for $s_2(J)$. We know that the diversity is determined by factor $\sqrt{|a(J)|^2+|b(J)|^2}$. The error probability can be written as

$$\begin{aligned} & P(s_2(2) \rightarrow error|a(J), b(J)) \\ & = Q\left(\sqrt{\frac{\rho|\sqrt{|a(J)|^2+|b(J)|^2}\mathbf{e}|_F^2}{4}}\right) \\ & \leq \exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)\mathbf{e}^\dagger\mathbf{e}}{4}\right) \\ & = \exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)e^2}{4}\right) \end{aligned} \tag{33}$$

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

$$E[a(J)\cdot b(J)|\alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] = 0 \tag{34}$$

So $a(J)$ and $b(J)$ are independent Gaussian random variables. We have

$$\begin{aligned} & P(s_2(J) \rightarrow error) \\ & = E[E[P(s_2(J) \rightarrow error|a(J), b(J))]| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] \\ & \leq E[E[\exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)e^2}{4}\right)\Bigg| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)]] \\ & = E[\frac{1}{\prod_{j=1}^2[1+\frac{\rho e^2}{4})]}| \\ & \qquad \alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] \\ & = \frac{1}{\prod_{j=1}^2[1+\frac{\rho e^2}{4})]} \end{aligned} \tag{35}$$

When ρ is large, Equation (35) becomes

$$P(s_2(J) \rightarrow error) \leq \rho^{-2}\left(\frac{e^2}{4}\right)^{-2} \tag{36}$$

By Equation (28), the diversity for $s_2(J)$ 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 3 users with two antennas and one receiver with 3 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 and 3 while QPSK is used in Figure 2 and 8-PSK is used in Figure 3. In each 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 while in Figure 3, 512-QAM is used. It is obvious that the proposed scheme has better performance which confirms the effectiveness of the interference cancellation scheme.

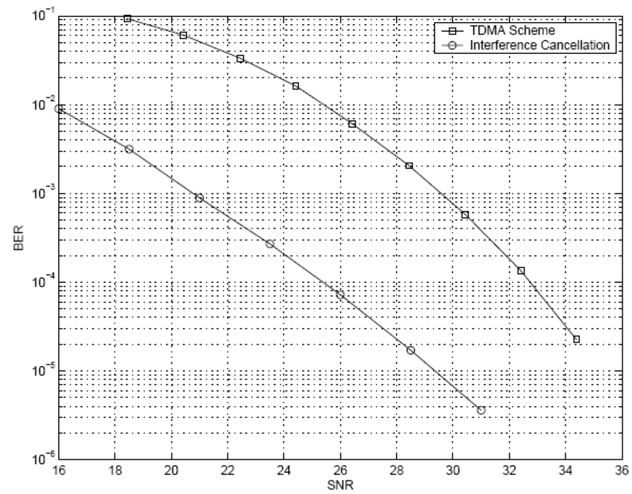

Fig. 2. QPSK constellation with interference cancellation

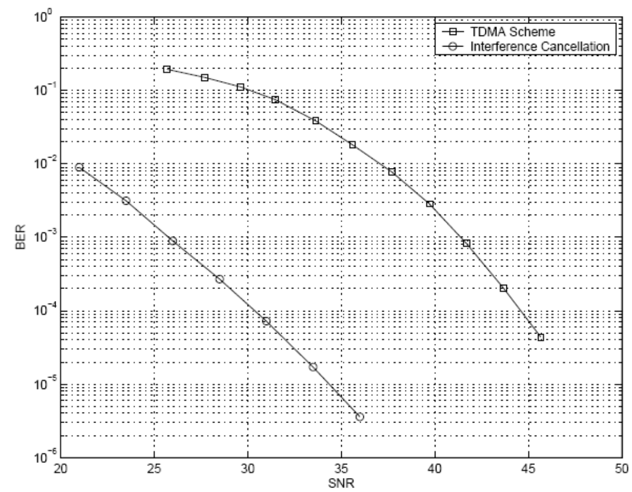

Fig. 3. 8-PSK constellation with interference cancellation

IV. Conclusions

In this paper, interference cancellation for multiple access channel is discussed for any number users with any number of antennas. 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. Simulations have confirmed our findings.

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