Multi-User Interference Management

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Abstract— MIMO Z Channel is investigated in this paper. We focus on how to tackle the interference when different users try to send their code words to their corresponding receivers while only one user will cause interference to the other. We assume there are two transmitters and two receivers each with two antennas. We propose a strategy to remove the interference while allowing different users transmit at the same time. Our strategy is low complexity while the performance is good. Mathematical analysis is provided and simulations are given based on our system.

Key Words— *Z Channel, Alamouti Codes, MIMO, Interference Cancellation, Complexity, Co-channel Interference*.

I. Introduction

Multiple-input multiple-output (MIMO) systems are a natural extension of developments in antenna array communication. The advantages of MIMO communication, which exploits the physical channel between many transmit and receive antennas, are currently receiving significant attention [1]–[12]. 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.

Multi-user MIMO or MU-MIMO is an enhanced form of MIMO technology that is gaining acceptance. 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.

Z interference channel is a network consisting 2 senders and 2 receivers. There exists a one-to-one correspondence between senders and receivers. Each sender only wants to communicate with its corresponding receiver, and each receiver only cares about the information form its corresponding sender. However,

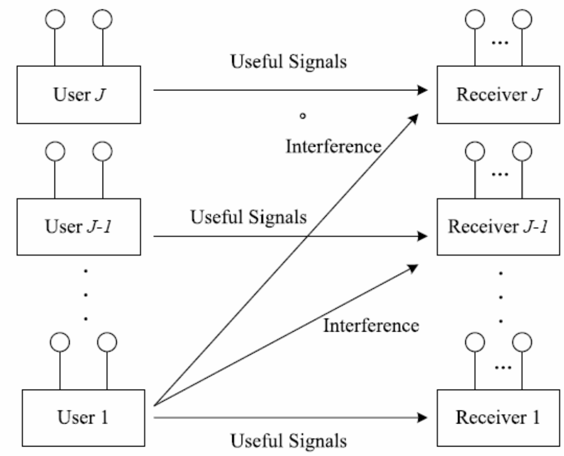

Fig. 1. Channel Model

a channel with strong signals may interfere other channels with weak signals while the channel with weak signals will not cause interference to the channel with strong signals. So Z interference channel has two principal links and an interference link. This scenario often occurs, when several sender-receiver pairs share a common media. The study of this kind of channel was studied in many literatures [13], [16]–[25]. However, this channel has not been solved in general case even in the general Gaussian case. In this paper, we focus on MIMO Z channels. Since each user transmits at the same time, how to deal with the cochannel interference is an interesting question. When channel knowledge is known at the transmitter, schemes to cancel the co-channel interference are proposed in [14], [15], [26]–[30].

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 there are J transmitters each with 2 transmit antennas and 2 receivers each equipped with J receive antennas. Each transmit sends codewords to different receivers. But only some users will cause interference to others. So this is a MIMO Z channel. 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

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

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) $\begin{pmatrix} a_1 & a_2 \\ -a_2^* & a_1^* \end{pmatrix}$ to a receiver equipped with at least J receive antennas. The received signal at the ith receive antenna of a given receiver with interference can be written in the following format:

$$\begin{pmatrix} r_{1,i} \\ r_{2,i} \end{pmatrix} = \sum_{j=1}^{J} \begin{pmatrix} s_1(j) & s_2(j) \\ -s_2(j)^* & s_1(j)^* \end{pmatrix} \begin{pmatrix} \alpha_{1,i}(j) \\ \alpha_{2,i}(j) \end{pmatrix} + \begin{pmatrix} \eta_{1,i} \\ \eta_{2,i} \end{pmatrix} \tag{7}$$

Here we assume J is the number of receivers with interference. The received signal at the ith receive antenna of a given receiver without interference can be written in the following format:

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

where $j \in \{1, \ldots, J\}$. 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. For the receiver with interference, at the ith antenna, we have

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

For the receiver without interference, at the ith antenna, we have

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

where $j \in \{1, \ldots, J\}$. 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 (11):

$$\begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix}\begin{pmatrix}r_{1,i}\\ r^*_{2,i}\end{pmatrix} = (|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)\begin{pmatrix}s^1_1\\ s^1_2\end{pmatrix} + \begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix}\sum_{j=2}^{J}\begin{pmatrix}\alpha_{1,i}(j) & \alpha_{2,i}(j)\\ \alpha^*_{2,i}(j) & -\alpha^*_{1,i}(j)\end{pmatrix}\begin{pmatrix}s_1(j)\\ s_2(j)\end{pmatrix} + \begin{pmatrix}\eta'_{1,i}\\ \eta'_{2,i}\end{pmatrix} \quad (11)$$

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

$$\begin{pmatrix}\eta'_{1,i}\\ \eta'_{2,i}\end{pmatrix} = \begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix}\begin{pmatrix}\eta_{1,i}\\ \eta_{2,i}\end{pmatrix} \quad (12)$$

In order to eliminate the effect of user 1, we need to divide both sides of Equation (11) by

$$\frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)} \quad (13)$$

Equations (11) becomes Equations (14):

$$\frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)}\begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix}\begin{pmatrix}r_{1,i}\\ r^*_{2,i}\end{pmatrix} = \begin{pmatrix}s^1_1\\ s^1_2\end{pmatrix} + \frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)}\begin{pmatrix}\eta'_{1,i}\\ \eta'_{2,i}\end{pmatrix} + \sum_{j=2}^{J}\frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)}\begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix} \times \begin{pmatrix}\alpha_{1,i}(j) & \alpha_{2,i}(j)\\ \alpha^*_{2,i}(j) & -\alpha^*_{1,i}(j)\end{pmatrix}\begin{pmatrix}s_1(j)\\ s_2(j)\end{pmatrix} \quad (14)$$

Then we can subtract both sides of Equation (14) from the equation when $i = 1$. The resulting terms are shown by

$$\widehat{y}(i) = \sum_{j=2}^{J}\widehat{H}(i)\begin{pmatrix}s_1(j)\\ s_2(j)\end{pmatrix} + \begin{pmatrix}\eta''_{1,i}\\ \eta''_{2,i}\end{pmatrix} \quad (15)$$

where $\widehat{y}(i)$ and $\widehat{H}(i)$, $i = 2, \ldots, J$, are given by Equations (16) and (17):

$$\widehat{y}(i) = \frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2}\begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix}\begin{pmatrix}r_{1,i}\\ r^*_{2,i}\end{pmatrix} - \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2}\begin{pmatrix}\alpha^*_{1,1}(1) & \alpha_{2,1}(1)\\ \alpha^*_{2,1}(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}r_{1,1}\\ r^*_{2,1}\end{pmatrix} \quad (16)$$

$$\widehat{H}(i) = \frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2}\begin{pmatrix}\alpha^*_{1,i}(1) & \alpha_{2,i}(1)\\ \alpha^*_{2,i}(1) & -\alpha_{1,i}(1)\end{pmatrix} \times \begin{pmatrix}\alpha_{1,i}(j) & \alpha_{2,i}(j)\\ \alpha^*_{2,i}(j) & -\alpha^*_{1,i}(j)\end{pmatrix} - \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2}\begin{pmatrix}\alpha^*_{1,1}(1) & \alpha_{2,1}(1)\\ \alpha^*_{2,1}(1) & -\alpha_{1,1}(1)\end{pmatrix}\begin{pmatrix}\alpha_{1,1}(j) & \alpha_{2,1}(j)\\ \alpha^*_{2,1}(j) & -\alpha^*_{1,1}(j)\end{pmatrix} \quad (17)$$

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

$$\begin{pmatrix}\eta''_{1,i}\\ \eta''_{2,i}\end{pmatrix} = \frac{1}{(|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2)}\begin{pmatrix}\eta'_{1,i}\\ \eta'_{2,i}\end{pmatrix} - \frac{1}{(|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2)}\begin{pmatrix}\eta'_{1,1}\\ \eta'_{2,1}\end{pmatrix} \quad (18)$$

The distribution of $\eta''_{1,i}$, $\eta''_{2,i}$ are Gaussian white noise. In Equation (17), $\widehat{H}(i)$ can be written as the following structure:

$$\widehat{H}(i) = \begin{pmatrix}a(i) & b(i)\\ b(i)^* & -a(i)^*\end{pmatrix} \quad (19)$$

where $a(i)$ and $b(i)$ are given by Equations (20) and (21):

$$a(i) = \frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2}[\alpha^*_{1,i}(1)\alpha_{1,i}(j) + \alpha_{2,i}(1)\alpha^*_{2,i}(j)] - \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2}[\alpha^*_{1,1}(1)\alpha_{1,1}(j) + \alpha_{2,1}(1)\alpha^*_{2,1}(j)] \quad (20)$$

$$b(i) = \frac{1}{|\alpha_{1,i}(1)|^2 + |\alpha_{2,i}(1)|^2}[\alpha^*_{1,i}(1)\alpha_{2,i}(j) - \alpha_{2,i}(1)\alpha^*_{1,i}(j)] - \frac{1}{|\alpha_{1,1}(1)|^2 + |\alpha_{2,1}(1)|^2}[\alpha^*_{1,1}(1)\alpha_{2,1}(j) - \alpha_{2,1}(1)\alpha^*_{1,1}(j)] \quad (21)$$

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:

$$\widehat{y}(J) = \widehat{H}(J)\begin{pmatrix} s_1(J) \\ s_2(J) \end{pmatrix} + \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (22)$$

In order to decode the $s_1(J)$, we can multiply both sides of the Equation (22) with $\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y}(J) = \begin{pmatrix} |a(J)|^2 + |b(J)|^2 & 0 \end{pmatrix}\begin{pmatrix} s_1(J) \\ s_2(J) \end{pmatrix} + \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix}$$
$$= (|a(J)|^2 + |b(J)|^2)s_1(J) + \begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (23)$$

In order to keep the Gaussian white noise, we need
In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a(J)|^2 + |b(J)|^2}s_1(J) + \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (24)$$

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

$$\widehat{s}_1(J) = \arg\min_{s_1(J)} \left| \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} a(J) \\ b(J)^* \end{pmatrix}^\dagger \widehat{y}(J) - \sqrt{|a(J)|^2 + |b(J)|^2}s_1(J) \right|_F^2 \quad (25)$$

So the decoding is symbol-by-symbol. In order to decode the $s_2(J)$, we can multiply both sides of the Equation (15) with $\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger$, we have

$$\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y}(J) = \begin{pmatrix} 0 & |a(J)|^2 + |b(J)|^2 \end{pmatrix}\begin{pmatrix} s_1(J) \\ s_2(J) \end{pmatrix} + \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix}$$
$$= (|a(J)|^2 + |b(J)|^2)s_2(J) + \begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (26)$$

In order to keep the Gaussian white noise, we need

$$\frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y} = \sqrt{|a(J)|^2 + |b(J)|^2}s_2(J) + \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta''_{1,J} \\ \eta''_{2,J} \end{pmatrix} \quad (27)$$

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

$$\widehat{s}_2(J) = \arg\min_{s_2(J)} \left| \frac{1}{\sqrt{|a(J)|^2 + |b(J)|^2}}\begin{pmatrix} b(J) \\ -a(J)^* \end{pmatrix}^\dagger \widehat{y}(J) - \sqrt{|a(J)|^2 + |b(J)|^2}s_2(J) \right|_F^2 \quad (28)$$

The decoding is also symbol-by-symbol. Follow the above procedures, we can detect signals with interference. For receiver without interference, we can consider Equation (10):

$$\begin{pmatrix} r_{1,i} \\ r^*_{2,i} \end{pmatrix} = \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}(j)^* & -\alpha_{1,i}(j)^* \end{pmatrix}\begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} + \begin{pmatrix} \eta_{1,i} \\ \eta^*_{2,i} \end{pmatrix} \quad (29)$$

We multiply $\begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}(j)^* & -\alpha_{1,i}(j)^* \end{pmatrix}^\dagger$ with both sides of the equation. we get

$$\begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}(j)^* & -\alpha_{1,i}(j)^* \end{pmatrix}^\dagger \begin{pmatrix} r_{1,i} \\ r^*_{2,i} \end{pmatrix} = \begin{pmatrix} \alpha_{1,i}(j)^2 + \alpha_{2,i}(j)^2 & 0 \\ 0 & \alpha_{1,i}(j)^2 + \alpha_{2,i}(j)^2 \end{pmatrix}\begin{pmatrix} s_1(j) \\ s_2(j) \end{pmatrix} + \begin{pmatrix} \alpha_{1,i}(j) & \alpha_{2,i}(j) \\ \alpha_{2,i}(j)^* & -\alpha_{1,i}(j)^* \end{pmatrix}^\dagger \begin{pmatrix} \eta_{1,i} \\ \eta^*_{2,i} \end{pmatrix} \quad (30)$$

Then we can detect signal without interference easily. Now we analyze the diversity. From Equation (23), we know that the diversity is determined by factor $\sqrt{|a(J)|^2 + |b(J)|^2}$. The diversity is defined as

$$d = -\lim_{\rho\to\infty} \frac{\log P_e}{\log \rho} \quad (31)$$

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

$$P(s_1(2) \to error|a,b) = Q\left(\sqrt{\frac{\rho|\sqrt{|a(J)|^2 + |b(J)|^2}\mathbf{e}|_F^2}{4}}\right) \le \exp\left(-\frac{\rho(|a(J)|^2 + |b(J)|^2)\mathbf{e}^\dagger\mathbf{e}}{4}\right) = \exp\left(-\frac{\rho(|a(J)|^2 + |b(J)|^2)e^2}{4}\right) \quad (32)$$

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

$$E[a(J)\cdot b(J)|\alpha_{1,2}(J), \alpha_{2,2}(J), \alpha_{1,1}(J), \alpha_{2,1}(J)] = 0 \quad (33)$$

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

We have

$$\begin{aligned}&P(s_1(2)\rightarrow error)\\&=E[E[P(s_1(2)\rightarrow error|a(J),b(J))]|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]\\&\leq E[E[\exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)e^2}{4}\right)\Bigg|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]]\\&=E[\frac{1}{\prod_{j=1}^{2}[1+\frac{\rho e^2}{4})]}|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]\\&=\frac{1}{\prod_{j=1}^{2}[1+\frac{\rho e^2}{4})]}\end{aligned}\tag{34}$$

When ρ is large, Equation (34) becomes

$$P(s_1(2)\rightarrow error)\leq\rho^{-2}\left(\frac{e^2}{4}\right)^{-2}\tag{35}$$

By Equation (31), 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

$$\begin{aligned}&P(s_2(2)\rightarrow error|a(J),b(J))\\&=Q\left(\sqrt{\frac{\rho|\sqrt{|a(J)|^2+|b(J)|^2}\mathbf{e}|_F^2}{4}}\right)\\&\leq\exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)\mathbf{e}^\dagger\mathbf{e}}{4}\right)\\&=\exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)e^2}{4}\right)\end{aligned}\tag{36}$$

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

$$E[a(J)\cdot b(J)|\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]=0\tag{37}$$

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

$$\begin{aligned}&P(s_2(J)\rightarrow error)\\&=E[E[P(s_2(J)\rightarrow error|a(J),b(J))]|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]\\&\leq E[E[\exp\left(-\frac{\rho(|a(J)|^2+|b(J)|^2)e^2}{4}\right)\Bigg|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]]\\&=E[\frac{1}{\prod_{j=1}^{2}[1+\frac{\rho e^2}{4})]}|\\&\qquad\alpha_{1,2}(J),\alpha_{2,2}(J),\alpha_{1,1}(J),\alpha_{2,1}(J)]\\&=\frac{1}{\prod_{j=1}^{2}[1+\frac{\rho e^2}{4})]}\end{aligned}\tag{38}$$

When ρ is large, Equation (38) becomes

$$P(s_2(J)\rightarrow error)\leq\rho^{-2}\left(\frac{e^2}{4}\right)^{-2}\tag{39}$$

By Equation (31), the diversity for $s_2(J)$ is 2. For the signals without interference, We have

$$\begin{aligned}&P(s_2(j)\rightarrow error)\\&=E[P(s_2(j)\rightarrow error)]|\alpha_{1,i}(j),\alpha_{2,i}(j)]\\&\leq E[\exp\left(-\frac{\rho\sum_{i=1}^{J}(|\alpha_{1,i}(j)|^2+|\alpha_{2,i}(j)|^2)e^2}{4}\right)\Bigg|\\&\alpha_{1,i}(j),\alpha_{2,i}(j)]\\&=\frac{1}{\prod_{j=1}^{2J}[1+\frac{\rho e^2}{4})]}\end{aligned}\tag{40}$$

When ρ is large, Equation (38) becomes

$$P(s_2(j)\rightarrow error)\leq\rho^{-2}\left(\frac{e^2}{4}\right)^{-2J}\tag{41}$$

By Equation (31), the diversity for $s_2(j)$ is $2J$.

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 3users with two antennas and two receivers each with 3 receive antennas. This is a typical MIMO Z 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.

IV. Conclusions

In this paper, we discuss the MIMO Z channel. We first give detailed description on MIMO Z channel. Later we show that how to tackle interference in such a system is important. Aiming to remove the interference, a strategy for MIMO Z channel is proposed and analyzed. We assume there are two transmitters and two receivers each with two antennas. The complexity of the strategy is low while the performance is good. Simulations confirm the theoretical analysis.

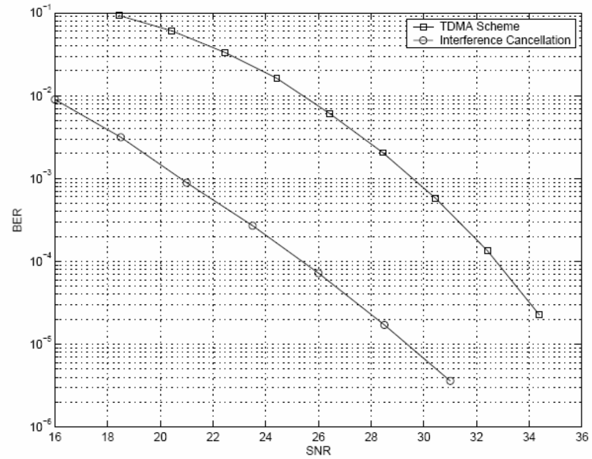

Fig. 2. QPSK constellation with interference cancellation

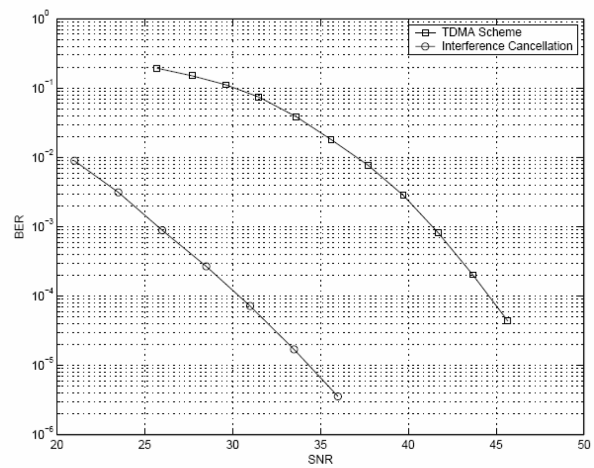

Fig. 3. 8-PSK constellation with interference cancellation

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