Proc. Annual Symposium on Research & Industrial Training, 02(2015) 165-170
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INTERFERENCE CANCELLATION BY A MODIFIED PRECODER FOR MULTIPLE USERS

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ABSTRACT

In multiple access channels, when users know each other's channels, precoders can be designed utilizing channel information to cancel the interference at the receiver without sacrificing the diversity or the complexity of the system. Recently, it was shown that when there are only two users, a receiver can completely cancels the interference of the two users and provides full diversity for each user. Unfortunately, the scheme only works for two users. In this paper, a system is proposed to achieve interference cancellation and full diversity with low complexity for any number of users.The main idea is to design precoders, using the channel information, to make it possible for different users to transmit over orthogonal directions. Then, using the orthogonality of the transmitted signals, the receiver can separate them and decode the signals independently.

Keywords: Multi-user detection, multiple antennas, interference cancellation, precoder, orthogonal designs

1. INTRODUCTION

Multiple-input multiple-output (MIMO) wireless channels, created by deploying antenna arrays at both transmitter and the receiver, promise high capacity and high quality wireless communication links. A lot of attention has been given to multi user detection schemes withsimple receiver structures. The multiple transmit and receive antennas are used to improve the gain, rate and reliability of wireless system[1].

In this paper a multiple antenna multi access scenario where interference cancellation is achieved by channel information is considered. When there is no channel information at the transmitter, simple array processing methods using orthogonal space-time block codes (OSTBC) and quasi-orthogonal space-time block codes (QOSTBC) have been proposed[2].

The common goal and the main characteristics of the above multi user system require less number of receive antennas and low complexity array decoding. However by using maximum likelihood detection, full diversity for each user is achieved. But maximum likelihood detection is usually not practical, as number of transmit and receive antennas increases, the number of users and bandwidth efficiency is also increased [3]. To overcome this drawback, channel information is utilized at the transmitters to increase the diversity of the system while keeping the low complexity of the decoding[6]. In other words, unlike the above mentioned methods, receive antennas are not used to cancel the interference. Instead, the channel information at the transmitter is used to design precoders that align different groups of signals along orthogonal directions [4]. As a result interference suppression is achieved without utilizing the receive antenna resources and therefore full diversity is achieved naturally.

2. EXPERIMENTAL

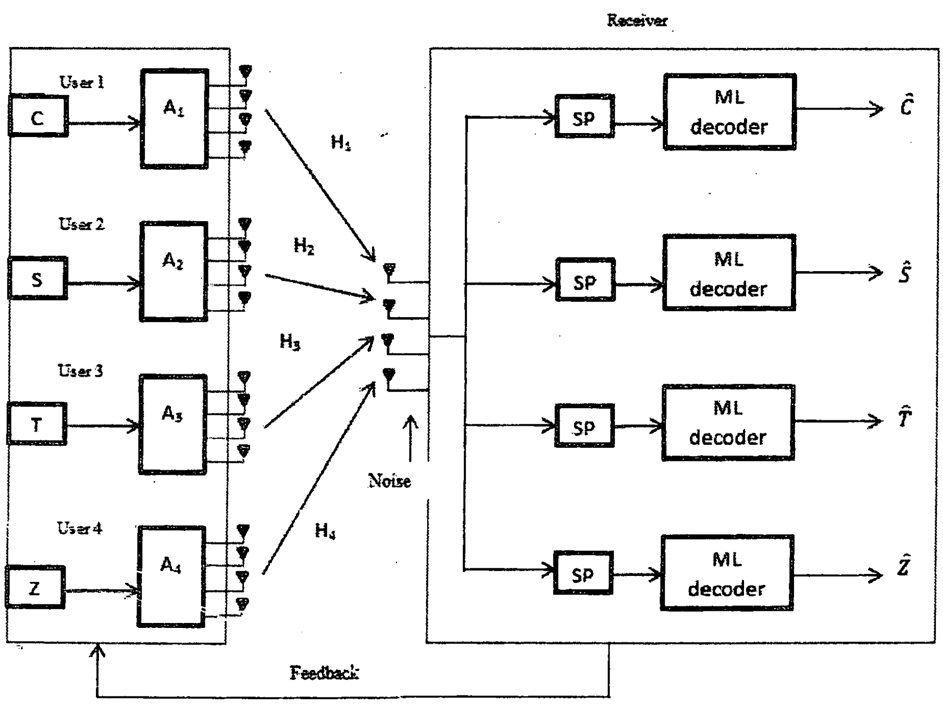

Figure 1: Block diagram of proposed system

In this paper, a quasi-static flat Rayleigh fading channel model is assumed. The path gains are independent complex Gaussian random variables and are fixed during the transmission of one block. In addition, a short term power constraint is assumed. For the sake of simplicity, the scheme is only presented for four users each with four transmit and one receive with four receive antennas. The block diagram of the system is shown in Figure 1. The channel matrices for users 1, 2, 3, 4 are assumed as[3],

$H_1=[h_1(i,j)]_{4\times4}$, $H_2=[h_2(i,j)]_{4\times4}$, $H_3=[h_3(i,j)]_{4\times4}$, $H_4=[h_4(i,j)]_{4\times4}$ [1]

respectively .At the lth time slots l=1, 2, 3, 4 the precoders for user 1,2,3,4 are,

$A^l_1=[a^l_1(i,j)]_{4\times4}$, $A^l_2=[a^l_2(i,j)]_{4\times4}$, $A^l_3=[a^l_3(i,j)]_{4\times4}$, $A^l_4=[a^l_4(i,j)]_{4\times4}$ [2]

In every 4 time slots, Users 1, 2, 3, 4 send QOSTBCs [5],

$$C=\begin{pmatrix} c1 & -c2* & c3 & -c4* \\ c2 & c1* & c4 & c3 \\ c3 & -c4* & c1 & -c2* \\ c4 & c3 & c2 & c1 \end{pmatrix} \qquad S=\begin{pmatrix} s1 & -s2* & s3 & -s4* \\ s2 & s1* & s4 & s3 \\ s3 & -s4* & s1 & -s2* \\ s4 & s3 & s2 & s1 \end{pmatrix}$$

2.1 Encoding:

According to the block diagram encoding and decoding parts are there along with the channel, as the channel is a quasi-static flat Rayleigh fading channel model. In this paper for results and for explanation only 4 users have been used. That is 4 users one receiver and 4 receiving antennas.

The four users at four different time slots suppose as l=1, 2, 3, 4. At the lth time slots l, l=1, 2, 3, 4 the input output equation can be written as,

$$yl=\sqrt{E_s}(H1A^l_1\ C(l)+H2A^l_2\ S(l)+H3\ A^l_3\ T(l)+H4A^l_4\ Z(l)+nl$$
$$=\sqrt{E_s}(H^l_1\ C(l)+H^l_2\ S(l)+H^l_3\ T(l)+H^l_4\ Z(l)+nl \qquad [3]$$

Where $H^l_i=H_iA^l_i$ and yl denotes the received signals of the four receive antennas at time slot *l*. Es denotes the transmit energy of each user; nl denotes the noise at the receiver at time slot *l*.Rearranging Equation (3), we have,

$$\overline{y}=\sqrt{E_s}\left(\overline{H1}\begin{pmatrix}c1\\c2\\c3\\c4\end{pmatrix}+\overline{H2}\begin{pmatrix}s1\\s2\\s3\\s4\end{pmatrix}+\overline{H3}\begin{pmatrix}t1\\t2\\t3\\t4\end{pmatrix}+\overline{H4}\begin{pmatrix}z1\\z2\\z3\\z4\end{pmatrix}\right)+\overline{n} \qquad [4]$$

Where,

$$\overline{y}=\begin{pmatrix}y1\\(y2)*\\y3\\(y4)*\end{pmatrix} \overline{n}=\begin{pmatrix}n1\\(n2)*\\n3\\(n4)*\end{pmatrix}$$

Now precoders have been chosen that can realize full diversity and interference cancellation for each user. To realize interference cancellation, a straight forward idea is to transmit the symbols of the four users along four orthogonal directions. By doing so, it is easy to achieve interference cancellation at the receiver using zero-forcing[2]. However, the difficulty lies in how to achieve full diversity as well. Here comes the concept of precoding technique which helps in improving the diversity and also removes the interference for four users. At each of the first 2 time slots, 1, 2, 3 and 4, precoders have been designed such that symbols of User 1 and symbols of User 2 are transmitted along two orthogonal directions respectively. Similarly precoders have been designed for Users 3 and 4, such that the transmit directions of their signals are orthogonal to each other. Finally after combining 1, 2, 3, 4 they all will not interfere because of the individual choosing of precoders symbols for 1,2 and 3, 4. As shown in the figure 2 they are placed in orthogonal structure in vector space.

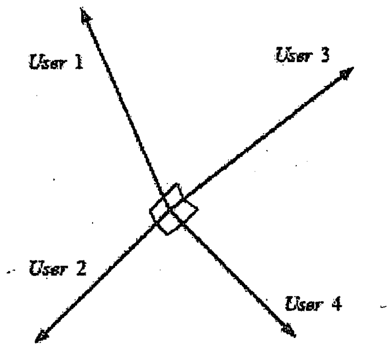

Figure 2: Orthogonal structure of signal vectors in 4-dimensional space.

2.2 Decoding

Using the pre-coders, Equation (3) becomes,

$$\overline{y} = \sqrt{Es}\left(\overline{H1}\begin{pmatrix} c1 \\ c2 \\ c3 \\ c4 \end{pmatrix} + \overline{H2}\begin{pmatrix} s1 \\ s2 \\ s3 \\ s4 \end{pmatrix} + \overline{H3}\begin{pmatrix} t1 \\ t2 \\ t3 \\ t4 \end{pmatrix} + \overline{H4}\begin{pmatrix} z1 \\ z2 \\ z3 \\ z4 \end{pmatrix}\right) + \overline{n} \qquad [5]$$

Here y and n are the same with y and n in Equation (3).Note that using the pre-coders, each column of matrix $\overline{H1}$ is orthogonal to each column of matrices$\overline{H2}$, $\overline{H3}$,$\overline{H4}$.

In order to decode symbols from User 1, both sides of Equation (5) is multiplied by matrix $\overline{H^{+}}_{1}$to achieve,

$$\overline{H^{+}}_{1}\overline{y} = \sqrt{Es}\,\overline{H^{+}}_{1}\overline{H1}\begin{pmatrix} c1 \\ c2 \\ c3 \\ c4 \end{pmatrix} + \overline{H^{+}}_{1}\overline{n} \qquad [6]$$

Similarly for user 2, 3, 4 we can multiply both sides of the equation (5) with matrix $\overline{H}^{+}{}_{2}, \overline{H}^{+}{}_{3}$ and $\overline{H}^{+}{}_{4}$ respectively to remove the signals of other user and use Maximum Likelihood Decoding to complete the decoding[6]. Here, it can be proved that full diversity can be achieved using this precoding scheme. Proof for User 1 is presented, since the proof for Users 2, 3, 4 is the same. Diversity is defined as:

$$d= - \lim_{\rho \to \infty} \left(\frac{\log Pe}{\log \rho} \right)$$

Where 'Pe' denotes the SNR and 'ρ' represents the probability of error.

3. RESULTS AND DISCUSSION

The performance of the proposed scheme is shown in Figure 3. The proposed scheme cancels the interference completely but provides a diversity of 16 by utilizing the channel information at the transmitter.

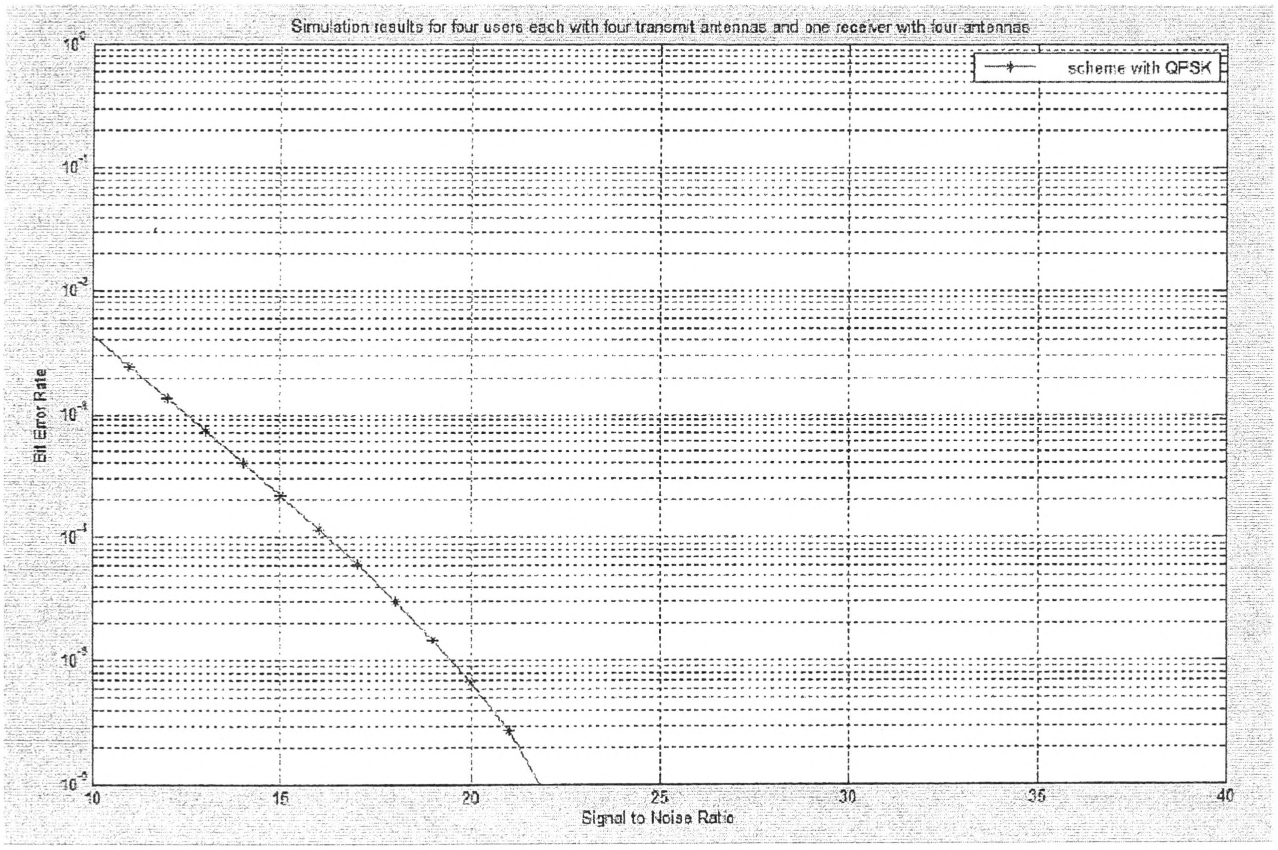

Figure 3: Simulation results for four users each with four transmit antenna and one receiver antenna.

4. CONCLUSION

In this paper, interference cancellation for a system with 4 users each with 4 transmits antennas and one receiver with 4 receive antennas have been considered. When users know all channels, a scheme was proposed to achieve Interference cancellation and achieve maximum possible diversity with low complexity. The main idea is that each user transmits signals along a direction that is orthogonal to direction of other users. This is achieved by designing precoders. Then the receiver can separate signals of different users using the orthogonality of the transmitted signals and Maximum Likelihood Decoding.

ACKNOWLEDGEMENTS

The Authors would like to convey their gratitude to the staff of Department of Electronics, Faculty of Applied Sciences, Wayamba University of Sri Lanka.

REFERENCES

[1]. Feng Li, Student Member, IEEE, and Hamid Jafarkhani,(2011) "Interference Cancellation and Detection for More than Two Users" IEEE transactions on communications, vol. 59, no. 3, pp. 901-910

[2]. Jafarkhani, H. (2001), "A quasi-orthogonal space-time block code," IEEE Trans. Communication, vol 49, no. 1, pp. 1-4.

[3]. Kazemitabar, J. and H.Jafarkhani, (2008) "Multiuser interference cancellation and detection for users with more than two transmit antennas," IEEE Trans. Commun., vol. 56, no. 4, pp. 574-583.

[4]. Li.Fung. and H.Jafarkhani,(2009), "Multiple-Antenna Interference Cancellation and Detection for Two Users Using Precoders," IEEE Sel. Topics Signal Process., vol. 3, no. 6, pp. 1066-1078.

[5]. Tarokh.V, H. Jafarkhani, and A. R. Calderbank,(1999), "Space-time block codes from orthogonal designs," IEEE Trans. Inf. Theory, vol. 45, pp. 1456-1467.

[6]. Tarokh, A.Naguib, N.Seshadri,andA.R.Calderbank,(1999),"Combined array processing and space-time coding," IEEE Transaction on Information Theory, vol. 45. pp. 1121-1128.