Space Time Code Design using Quadrature Amplitude Modulation for Multiple Access Channel with Quantized Feedback

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Abstract— Space time block codes for multiple access channels with full diversity and low decoding complexity for any number of transmitters and one receiver with quantized feedback. We provide detail of our scheme for four transmitter and four antennas. Each transmitter sends code word to the receiver at the same time. First propose a codebook design and feedback scheme that combines space time block coding and array processing. To the best of our knowledge this is the first scheme with quantized feedback that can achieve low decoding complexity and full diversity for any number of users when all users transmit at the same time. The QAM Scheme can implement low decoding complexity differential modulation it can be used to increase the bit error rate and signal to noise ratio. The performance of TDMA System in AWGN channel shows that QAM modulation technique has better performance compared to that of QPSK.

I. INTRODUCTION

Space time coding also applied in multiple access channels to enhance the system performance. Recently several space-time processing techniques have been used in MAC to reduce the decoding complexity and enhance system performance by cancelling the interference from different users. When perfect channel information is not available at the transmitter, no scheme exists that can achieve the interference cancellation and full diversity for any number of transmitters. We define full diversity as the maximum possible diversity of a single user system with the same number of transmit and receive antennas.

A Straightforward way is to use time division multiple access and let each transmitter send space time code to the receiver at different time slots. TDMA can achieve low decoding complexity and full diversity. However in this case the symbol rate for each user will only be 1/j. where j is the number of users. To avoid the symbol rate loss, interference cancellation techniques base on space time code can be used to allow simultaneous transmission. To the best of our knowledge ,when space time code are used to enhance the system performance, there is no scheme in the literature that can achieve full diversity and low decoding complexity and symbol rate one simultaneously. In this paper, we define symbol rate as the number of symbol transmitted per user per time slot.

The main idea is to solve this problem is to design proper code book, recoding and decoding scheme using space time block coding and quantized feedback at the transmitter.by choosing proper pre-coder from our proposed codebook, we can achieve full diversity, low decoding complexity based on interference cancellation and symbol rate one simultaneously. In this paper, we assume that our system operates under short term power constraints, fixed code work block length and limited time delay.

The goal of combining beam forming and space time coding in this work is to obtain full diversity order and to provide additional received power compared to conventional space time codes. In our system, we consider a quasi-static fading environment and we incorporate both high rate and low rate feedback channels with positive feedback errors. To utilize feedback information, a class of code constellations is proposed inspired from orthogonal designs and pre-coded space time block codes generalized partly orthogonal designs or generalized POD. Then we design the quantize for the erroneous feedback channel and the pre-coder codebook of PODs based on this criterion. The quantized scheme in our system is a channel optimized vector quantizer (COVQ)

II. MULTIPLE ACCESS CHANNEL MODEL

Let us consider multiple access channel model shown in fig 1.

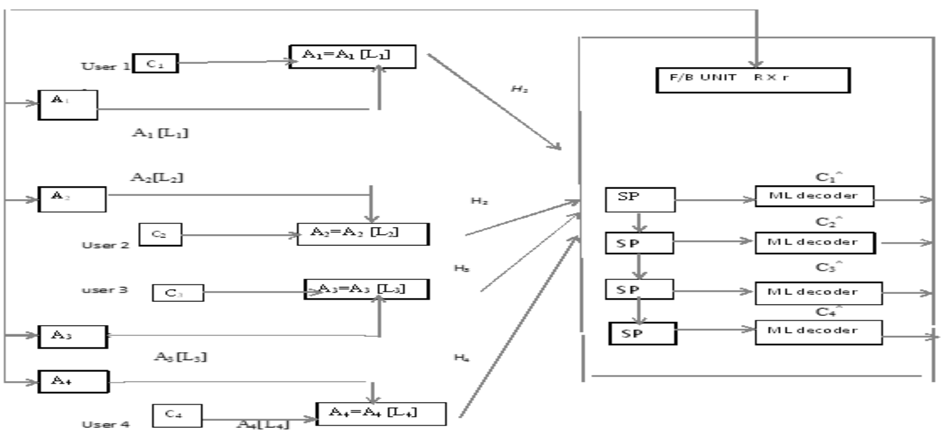

Fig. 1: multiple access channel

We first assume that there are 4 users each with 4 transmit antennas and one receiver with 4 receives antennas. All user send different space time codes to the receiver on the same frequency band at the same time. When channel knowledge is not available at the transmitters, space time block coding combined with TDMA can achieve low decoding complexity and full diversity. But the symbol rate will be reduced one fourth of that space time code. The symbol rate unchanged when space time code is used is to combine space time coding and array processing. In otherwords, we allow all transmitter to send space time code simultaneously to keep rate one and utilize special array processing techniques to achieve low decoding complexity and full diversity.

First let us introduce the input and output equations. In every four time slot user1, 2, 3, 4 send the quasi orthogonal space time block codes. (QOSTBC).

The channel are quasi Rayleigh flat fading are constant during four time slots. We use to denote the channel matrix between user and receivers, and then the received signals at the time slot are,

$$Y^t = H_1 A_1 C_1(t) + H_2 A_2 C_2(t) + H_3 A_3 C_3(t) + H_4 A_4 C_4(t) + n^t$$

III. PRE-CODER DESIGN AND INTERFERENCE CANCELLATION

Pre-coding is a generalization of beam forming to support multilayer transmission in multiple antenna wireless communications. In conventional single layer beam forming the same signal is emitted from each transmit antennas with appropriate weighting such that the signal power is maximized at the receiver output. When the receiver has multiple antennas, single layer beam forming cannot maximized simultaneously maximize the signal level at all of the receive antennas. Thus, in order to maximize the through put in multiple receive antenna systems, multilayer beam forming required.

IV. DIVERSITY MULTIPLEXING AND TRADE OFF

Multiple antenna provides two different types of benefits in a fading channel: diversity gain and multiplexing gain. For a fixed rate of transmission , the error probability can decay with SNR as fast as

$$P_e \sim \frac{1}{SNR^{mn}}$$

The factor mn is called the maximal diversity gain, obtained by averaging over the mn independent channels gains between all the antenna pairs. In this context, multiple antennas provide additional reliability over single-antenna systems to compensate for the randomness due to fading.

On the other hand, the random less due to fading can be *taken advantage* of by creating parallel spatial channels. This concept is best motivated by a capacity result: It showed that the *ergodic capacity* of the multiple-antenna channel scales like

$$C(SNR) \sim MIN(m,n) \log(SNR)$$

at high SNR. The parameter min(m,n)is the number of degrees of freedom in the channel and yields the maximum amount of spatial multiplexing gain possible. The ergodic capacity is achieved by averaging over the variation of the channel over time. In the slow fading scenario, no such averaging is possible and one cannot communicate at the capacity C(SNR) reliably. On the other hand, to achieve the maximal diversity gain Mn, one needs to communicate at a *fixed* rate R , which becomes very small compared to the capacity at high SNR. This suggests a more interesting formulation of asking what is the largest diversity gain that can be achieved if one wants to communicate at a fixed *fraction* of the capacity. It leads to a formulation of the tradeoff between diversity and multiplexing gains, which we formalize below.

We think of a scheme {C(SNR)} as a family of codes, coding over one single coherence block, one at each SNR level. Let R(SNR)& Pe(SNR) and denote their data rate (in bits per symbol period) and the ML probability of detection error, respectively.

A scheme {C(SNR)} is said to achieve spatial multiplexing gain r and *diversity gain d* if the data rate

$$\lim_{SNR\to\infty} \frac{R(SNR)}{\log(SNR)}$$

And the average error probability,

$$\lim_{SNR\to\infty} \frac{\log p \log p_e(SNR)}{\log(SNR)}$$

V. ADDITIVE WHITE GAUSSIAN NOISE

A basic and generally accepted model for thermal noise in communication channels, is the set of assumptions that The noise is additive, i.e., the received signal equals the transmit signal plus some noise, where the noise is statistically independent of the signal. The noise is white, i.e., the power spectral density is flat, so the autocorrelation of the noise in time domain is zero for any non-zero time offset. The noise samples have a Gaussian distribution. Mostly it is also assumed that the channel is Linear and Time Invariant. The most basic results further assume that it is also frequency non-selective. Consider a minimal-delay space-time coded Rayleigh quasi static flat fading MIMO channel with full channel state information at the receiver (CSIR). The input output relation for such a system is given by

$$Y=HX+N$$

Designing STBCs with low decoding complexity has been studied widely in the literature. Orthogonal designs with single symbol decidability. For STBCs with more than two transmit antennas, these came at a cost of reduced transmission rates. To increase the rate at the cost of higher decoding complexity, multi-group decodable STBCs were introduced .

Fast de-codable codes have reduced SD complexity owing to the fact that a few of the variables can be decoded as single symbols or in groups if we condition them with respect to the other variables.

VI. DE-CODING WITH LOW COMPLEXITY

Decoding is defined as retrieving the data from one format to another format. Using the pre-coders becomes

$$y' = \left(H_1' \begin{pmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{pmatrix} + H_2' \begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{pmatrix} + H_3' \begin{pmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \end{pmatrix} + H_4' \begin{pmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{pmatrix} \right) + n'$$

In order to decode symbols from User 1, So if QAM is used,

$$\hat{H}^{-1}\,\mathrm{Re}\left\{\overline{H}_1^{\dagger}\,\overline{y}\right\} = \sqrt{E_s}\,\hat{H}\begin{pmatrix} c_{1R} \\ c_{2R} \\ c_{3R} \\ c_{4R} \end{pmatrix} + \mathrm{Re}\{\hat{n}\}$$

$$\hat{H}^{-1}\,\mathrm{Im}\left\{\overline{H}_1^{\dagger}\,\overline{y}\right\} = \sqrt{E_s}\,\hat{H}\begin{pmatrix} c_{1R} \\ c_{2R} \\ c_{3R} \\ c_{4R} \end{pmatrix} + \mathrm{Im}\{\hat{n}\}$$

VII. MAXIMAL LIKELIHOOD METHOD

Maximal likelihood method it can be used to estimate the parameter of a statically model. Maximal likelihood method to decode the real and imaginary part separately.

$$imag\left\{(H^{+}H)\frac{-1}{2}H^{+}Y_1\right\}$$

$$=\sqrt{E_S}(H^{+}H)\frac{1}{2}\ imag\begin{pmatrix} c_{11} \\ c_{12} \\ c_{13} \\ c_{14} \end{pmatrix}+imag\left\{(H^{+}H)\frac{-1}{2}H^{+}\,n_1\right\}$$

$$real\left\{(H^{+}H)\frac{-1}{2}H^{+}Y_1\right\}$$

$$=\sqrt{E_S}(H^{+}H)\frac{1}{2}\ real\begin{pmatrix} c_{11} \\ c_{12} \\ c_{13} \\ c_{14} \end{pmatrix}+real\left\{(H^{+}H)\frac{-1}{2}H^{+}\,n_1\right\}$$

VIII. DIVERSITY ANALYSIS AND FEEDBACK DESIGN

In this section,we show how to achieve full diversity by designing the feedback scheme and codebook.we only prove that the diversity for C_{11}, C_{12}, C_{13}, C_{14},from user 1 is full.the proof for user 2,3,4 sType equation here.imilar.After ML Decoding we get,

$$\mathbf{e} = \begin{pmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{pmatrix} = \begin{pmatrix} c_{11} \\ c_{12} \\ c_{13} \\ c_{14} \end{pmatrix} - \begin{pmatrix} \hat{c}_{11} \\ \hat{c}_{12} \\ \hat{c}_{13} \\ \hat{c}_{14} \end{pmatrix}$$

IX. PAIR WISE ERROR PROBABILITY

Pair wise error probability it is the error probability because probability exist takes a pair of signal vector signal constellation pairwise error probability for C_{11},C_{12}, C_{13}, C_{14} it can be written as

$$P(\mathbf{c}\rightarrow\bar{\mathbf{c}}\,|\,\mathbf{H}) = Q\left(\sqrt{\frac{\rho\|(\mathbf{H}^{\dagger}\mathbf{H})^{\frac{1}{2}}\mathbf{Re}\|_F^2}{4}}\right)$$
$$= Q\left(\sqrt{\frac{\rho\mathbf{e}^{\dagger}\mathbf{R}^{\dagger}\mathbf{H}^{\dagger}\mathbf{H}\mathbf{R}\mathbf{e}}{4}}\right)$$
$$\leq \exp\left(-\frac{\rho\mathbf{e}^{\dagger}\mathbf{R}^{\dagger}\mathbf{H}^{\dagger}\mathbf{H}\mathbf{R}\mathbf{e}}{8}\right)$$

$$e^{\wedge} = \begin{pmatrix} c_{11} \\ c_{12} \\ c_{13} \\ c_{14} \end{pmatrix} = Re$$

X. SIMULATION RESULTS

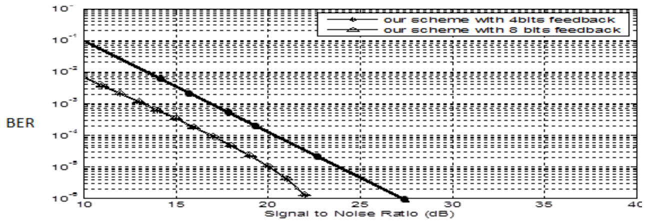

Fig. 2: simulation result for 4 userseach with 4 transmit antenna one receiver with 4 receive antennas.The constellation of QAM 4 or 8 bits of feedback are used.

XI. CONCLUSION

In this paper propose a quantized feedback transmission scheme for multiple access channels with any number of users by combining array processing and space-time block coding to achieve full diversity and low decoding complexity. We first propose a pre-coding and decoding scheme to achieve interference cancellation. Then we propose a codebook and feedback design to achieve full diversity. To the best of our knowledge, this is the first scheme to achieve full diversity and low-complexity decoding for multiple access channels with any number of users when all users transmit simultaneously with only quantized feedback. The QAM Scheme can implement low decoding complexity differential modulation it can be used to increase the bit error rate and signal to noise ratio. The performance of TDMA system in AWGN channel shows that QAM modulation technique has a better performance compared to that of QPSK.

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