A Precoding Scheme to Improve Performances of MIMO Systems

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Abstract. MIMO technology can be divided into two ways: based on the spatial multiplexing technique, such as VBLAST, and based on the launch diversity technology, such as STBC. This paper proposes a structure which mixes the two ways, that is STBC-VBLAST structure. In principle of minimizing pair-error probability, we design the precoding matrix of this system using the features beam molding algorithm. This proposal is suitable for TDD mode. It takes advantage of CSI to reduce error rate and increase capacity. Simulation results show that this algorithm could achieve remarkable effects, especially in low constellation dimension.

Keywords: MIMO, Precoding, Features beam shaping.

1 Introduction

MIMO (multi-input multi-output)[1]system which is good at channel capacity and diversitygain, is regarded as the development direction of the future wireless communication system. In 1990s based on the multiple antenna channel sending principle, there is a new technology—Space-time codes. According to the different designing methods it can be divided into two ways: based on the spatial multiplexing technique, such as VBLAST (vertical bell layered space-time code), and based on the launch diversity technology, such as STBC (space-time block codes).

This paper proposes a STBC-VBLAST mixing system [2] , and design the precode of sending signal.

2 STBC-VBLAST System Precoding Model

In Ref. [3] Lan Zhao etc. come up with the STBC-VBLAST composite structure, that is, multiple STBC code block reuse in space, and transmit at the same time, the receiver detect by group and decode the multiple STBC code block one by one. Tianyu Mao etc. propose a new STBC-VBLAST mixing scheme in Ref. [4]. They use VBLAST transmission scheme in some antennas, while in the remaining antennas

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reuse the multiple STBC code blocks together to transmit, the receiver use sorting continuous interference eliminate QR assay to decode. In Ref. [5] proposed a precoding transmission scheme based on the structure of Ref. [4], it improves the original system considerably both in the flat decline and frequency selective fading channel.

This paper using the known CSI (channel status information) of transmitter propose a precoding transmission scheme based on the STBC-VBLAST mixing structure in Ref. [3],.This scheme referencing the features beam molding algorithm of the monolayer STBC system in Ref. [6], process the each STBC layer's independent feature beam molding on STBC-VBLAST mixing structure.

The precoding system scheme of STBC-VBLAST composite structure is shown as Fig.1.

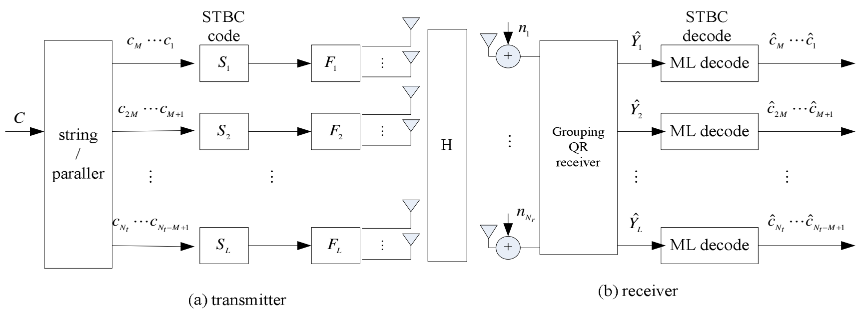

Fig. 1. STBC-VBLAST precoding system scheme

We suppose that the number of transmitting and receiving antenna is N_t and N_r ($N_r \geq N_t$). The original sending signal is $C = \begin{bmatrix} c_1 & c_2 & \cdots & c_{N_t} \end{bmatrix}$. The number of STBC code blocks reuse layer is L. Every layer using its code elements to STBC code, form S_u ($1 \leq u \leq L$) which is $M \times T$ dimension matrix, standing for sending M code element symbols in T time piece. Each STBC layer process by linear precoding matrix, finally reuse the signal on N_t antennas to transmit. The value of M is decided by the STBC code scheme we taken, e.g. if we take G2 (Alamouti) code [7] scheme, M=2, L=N_t/2, as Fig.2 shown.

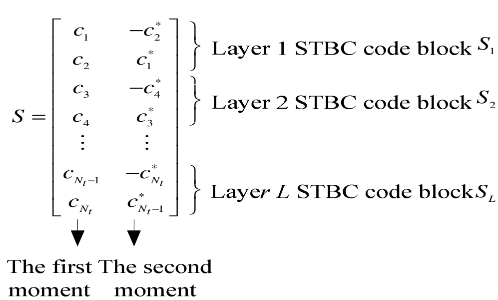

Fig. 2. Piece layered schemes in G2 code scheme

Transmitting signals across a quasi-static flat Rayleigh fading channel H, arrive at the receiver.

The received signal is $Y = HFS + n$, F is the precoding matrix whose designing method is expressed in part **3**. n is the $N_r \times T$ dimensional complex Gaussian white noise, in which each element obeys the mean for 0, variance for $\delta^2/2$ Gaussian distribution independently. Then the receiver divides the equivalent matrix HF by QR to gain the sufficient statistics $\hat{Y} = Q^H Y = RS + \hat{n}$. It processes R by the layers of the transmitter, to draw the equivalent son channel which is corresponded each layer's signal coded by STBC matrix R_{uu}.

Signal $\hat{Y}$ and noise $\hat{n}$ also take the block process, so after the STBC coded signal of layer u S_u transmitted to the receiver, the received signal is expressed as (1).

$$\hat{y}_u = R_{u,u} S_u + \sum_{l=u+1}^{L} R_{u,l} S_l + \hat{n}_u, 1 \le u \le L \tag{1}$$

The receiver decodes from layer L layer by layer. When STBC decode in each layer, we use ML (maximum likelihood) decode [8], gaining code element of the signal of layer u is $\hat{c}_{(u-1)M+1} \cdots \hat{c}_{uM}$.

3 The Design of Precoding Based on the Composite Structure

According to the transmitting antenna corresponding different STBC code block, we make every adjacent M line of the channel matrix $H = [H_1 \quad H_2 \quad \cdots \quad H_L]$. H_u is the $N_r \times M$ dimensional channel son matrix composed by the $(u\text{-}1)M+1$ line and the uM line. To reduce the interference between each layer effectively, we need precode each layer independently. Its structure is as (2) shown.

$$F = \begin{bmatrix} F_1 & 0 & \cdots & 0 \\ 0 & F_2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & F_L \end{bmatrix} \tag{2}$$

In (2), F_u is $M \times M$ dimensional matrix, represent the precoding matrix which is corresponding with the STBC code block of layer u. We can design F_u according to the principle of making paired mistake rate of layer u. The paired error probability of layer u STBC boundary meets (3).

$$P(S_u \to \hat{S}_u) \le [\det(I + H_u F_u (S_u - \hat{S}_u)(S_u - \hat{S}_u)^H F_u^H H_u^H)]^{-N_r} \tag{3}$$

In order to make (3) minimum, F_u in meeting energy constraint conditions, need to make (4) maximum.

$$\max_{tr(F_u F_u^H) < E_S} \det(I + H_u F_u (S_u - \hat{S}_u)(S_u - \hat{S}_u)^H F_u^H H_u^H) \tag{4}$$

If the code words differential matrix is $W_u = (S_u - \hat{S}_u)(S_u - \hat{S}_u)^H$, the transmitter divides H_u by QR matrix $H_u = Q'_{u,u} R'_{u,u}$, we can gain $\max_{tr(F_u F_u^H) < E_S} \det[I_M + R'_{u,u} F_u W_{ss,u} (F_u)^H (R'_{u,u})^H / \delta_n^2]$. Make singular value decomposition to $R'_{u,u}$, $R'_{u,u} = U_u \Lambda_u V_u^H$. Diagonal matrix $\Lambda_u = diag\begin{bmatrix} \lambda_{R_{u,u},1} & \lambda_{R_{u,u},2} & \cdots & \lambda_{R_{u,u},M} \end{bmatrix}$, each non-zero elements is in descending order. We gain (5).

$$\begin{aligned} &\max_{tr(F_u F_u^H) < E_S} \det\left(I_M + \frac{1}{\delta_n^2} U_u \Lambda_u V_u^H F_u W_{ss,u} F_u^H V_u \Lambda_u U_u^H \right) \\ &= \max_{tr(F_u F_u^H) < E_S} \det\left(I_M + \frac{1}{\delta_n^2} \Lambda_u V_u^H F_u W_{ss,u} F_u^H V_u \Lambda_u \right) \end{aligned} \tag{5}$$

In terms of Hadamard inequality, arbitrary phalanx B meets: $\det(B) \le \prod_i B_{i,i}$, '=' is obtained when the B for diagonal matrix. So if (5) is maximum, we must assure the matrix in det(.) is diagonal matrix. Due to using orthogonal STBC code, $W_{ss,u} = \alpha I$, α is decided by different modulation dimension and STBC code scheme. (5) can be written into (6).

$$\max_{tr(F_u F_u^H) < E_S} \det\left(I_M + \frac{\alpha}{\delta_n^2} \Lambda_u V_u^H F_u F_u^H V_u \Lambda_u \right) \tag{6}$$

When the eigenmatrix of $F_u F_u^H$ match V_u, just meeting $F_u F_u^H = V_u P_u V_u^H$, and the matrix in det(.) is diagonal matrix, (6) can gain the maximum. At this moment the precoding matrix of layer u is $F_u = V_u P_u^{1/2}$. V_u is features beam forming direction, P_u is diagonal matrix, representing the energy distribution of each beam direction, each element on diagonal line obeys the water-filling distribute.

Making each STBC code block of layer $1 \cdots L$ diagonalization according to the above method, finally we can gain the precoding matrix F, just as (2) shown. If analyzing the design of precoding matrix by making the channel ergodic capacity biggest, we gain that the channel capacity of layer u is described as (7).

$$C_u = \max_{tr(F_u F_u^H) < E_S} \log_2 \det(I_{N_r} + H_u F_u S_u S_u^H F_u^H H_u^H / \delta_n^2) \tag{7}$$

Seeking for the question of making (7) maximization is equivalent with the question of making (4) maximization. So the STBC-VBLAST precoding system based on the above features beam shaping method can make the BER (bit error rate) lower effectively and improve the channel capacity.

4 Simulations

Flat Rayleigh fading channel model is used in simulations. H is the $N_r \times N$ dimensional matrix in which each element obeys the mean for 0, variance for 1 Gaussian distribution. The system has four transmitting antennas and four receiving antennas. Ready to send signal is divided into 2 layers. Each layer adopts G2 code scheme to STBC code, just Alamouti code.

We first use common STBC-VBLAST structure to send signals, getting the curve expressed by "-o-"; then we use the precoding STBC-VBLAST structure proposed by this paper to transmit, getting the curve expressed by "-*-".

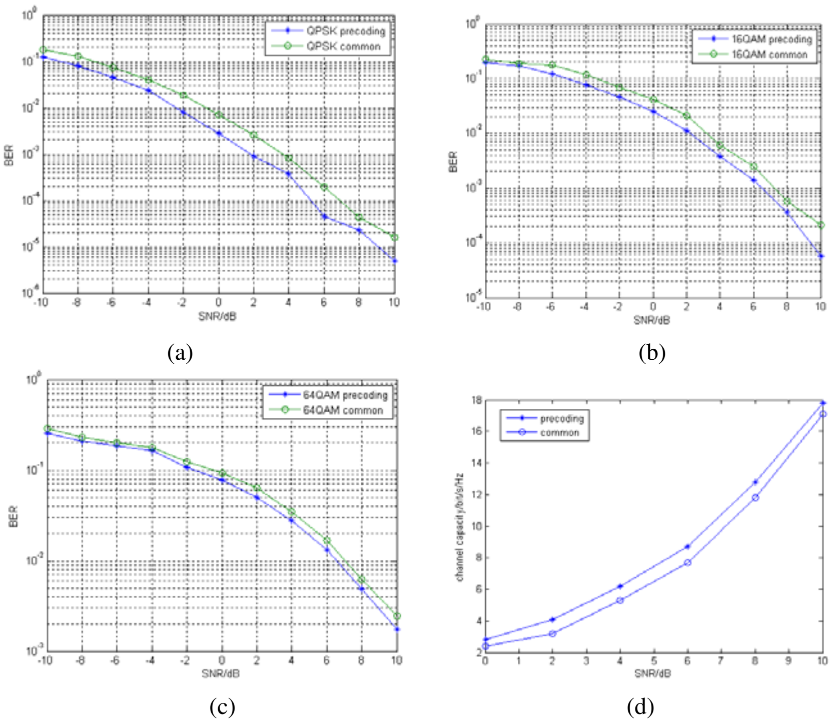

Fig. 3. BER and channel capacity of precoding and common STBC-VBLAST system

In Fig.3 (a)(b)(c), horizontal ordinate is SNR (signal to noise ratio) whose unit is dB. Vertical axis is BER. We compare the BER of the two methods under QPSK, 16QAM and 64QAM signal modulation. According them, we can make the blow conclusion. In Fig.3(a) QPSK modulation, the algorithm of feature beam molding proposed in this paper can make the system precoding gain reach about 2dB; In Fig.3(b) 16QAM modulation, the gain can reach about 0.5 dB; In Fig.3(c) 64QAM modulation, the precoding gain is about 0.1~0.2 dB. So, by comparing we can obtain that at the same SNR condition feature beam molding precoding algorithm can improve the system BER, but along with the increasing of modulation dimension, the performance of BER improving has reduced.

Fig.3 (d) simulates the traversal channel capacity of low SNR in QPSK modulation. The channel capacity of the precoding STBC-VBLAST system is improved to some extent than the common system, but increment is limited.

5 Conclusions

In this paper we propose a precoding scheme for STBC-VBLAST mixing structure. This method designs the precoding matrix on the principle of making the paired error probability of the system smallest or the channel capacity maximum by the feature beam molding algorithm.

The simulation use Matlab shows that in the same condition of SNR, the method proposed in this paper can make the utmost of the CSI, effectively reduce the BER of STBC-VBLAST system and improve the channel capacity. In the flat Rayleigh fading channel, using low dimension signal modulation the effect is more apparent. In the paper we only discussed the flat Rayleigh fading channel. Making the MIMO-OFDM system self-adapting transmission according to the different channel conditions is an important way in future.

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