

An improved linear dispersion codes transmission scheme based on OSIC detection

Shi Feng Chen Ming Cheng Shixin

(National Mobile Communications Research Laboratory, Southeast University, Nanjing 210096, China)

Abstract: Linear dispersion codes (LDCs) were originally designed based on maximum likelihood detection. They do not have good performance when using ordered successive interference cancellation (OSIC) detection. In this paper, we propose a new improved linear dispersion codes transmission scheme to combat performance loss of original LDCs when using OSIC detection. We introduce an interleaver to each data substream transmitted over different antennas after LDCs encoder. Furthermore, a new computer search criterion for a linear transformation matrix is also proposed. New search criterion is to minimize the symbol error rate based on OSIC detection. Computer simulations show that the performance of proposed LDCs transmission scheme is better than the original LDCs.

Key words: linear dispersion codes; space-time codes; interleaver; ordered successive interference cancellation (OSIC) detection

Multiple-input multiple-output (MIMO) wireless transmission has been proved to be a promising technique to support high data rate transmission^[1,2]. Space-time codes such as space-time block codes (STBC)^[3] and space-time trellis codes (STTC)^[4] are designed to decrease error probability of data transmission for MIMO systems. Although an expected performance can be guaranteed, a high spectral efficiency or relatively full MIMO channel capacity cannot be obtained by STTC and STBC. On the contrary, Bell labs layered space-time (BLAST) architecture^[5] has high spectral efficiency instead of BER performance since it does not exploit the transmission diversity.

To optimize both channel capacity and error probability, linear dispersion codes were proposed in Refs. [6, 7]. The transmitted codeword of linear dispersion codes (LDCs) is a matrix in which all transmitted symbols are dispersed by the dispersion matrices. However, the LDCs proposed in Refs. [6, 7] do not have good performance when using ordered successive interference cancellation (OSIC) detection.

In this paper, we propose a new improved linear dispersion codes structure by introducing an interleaver to the data substream transmitted in each antenna after LDCs encoder. Furthermore, a new computer search criterion for a linear transformation matrix is proposed. Our designs are given under the environment of a flat fading channel, and the channel coefficients are assumed to be independent and

identically distributed complex Gaussian random variables and known perfectly at the receiver.

1 System Model

We consider an MIMO system with M_t transmitting antennas and M_r receiving antennas. We will use the same system model in Ref. [7]. Fig.1

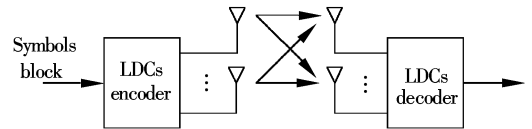


Fig.1 Diagram of original LDCs system

shows the diagram of the original LDCs system. Let $\{s_1, s_2, \dots, s_N\}$ be a symbol sequence transmitted in T symbol periods. And let \mathbf{M}_n be the $M_t \times T$ dispersion matrix corresponding to the transmitted symbol s_n for $1 \leq n \leq N$, and satisfy the following power constraint:

$$\text{tr}\{\mathbf{M}_n \mathbf{M}_n^H\} = \frac{T}{N} \quad 1 \leq n \leq N \quad (1)$$

where $\text{tr}\{\}$ is the trace function. Then the transmitted codeword can be written as

$$\mathbf{S} = \sum_{n=1}^N s_n \mathbf{M}_n \quad (2)$$

Eq.(2) implies that N transmitted symbols are dispersed at M_t transmit antennas and T symbol periods and transmitted simultaneously.

After matched filtering and symbol rate sampling, the received signal vector at the i -th time slot can be expressed as

$$\mathbf{y}_i = \sqrt{E_s} \mathbf{H} \tilde{\mathbf{S}}_i + \mathbf{v}_i \quad 1 \leq i \leq T \quad (3)$$

where \mathbf{H} is the $M_r \times M_t$ MIMO channel matrix of which entries are independent complex Gaussian

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Biographies: Shi Feng (1975—), male, graduate; Cheng Shixin (corresponding author), male, professor, sxcheng@seu.edu.cn.

random variable with zero-mean and unit variance, \tilde{S}_i is the i -th column vector of codeword matrix \tilde{S} , and \mathbf{v}_i is an $M_r \times 1$ noise vector of which entries are independent complex Gaussian random variables with zero-mean and variance $N_0/2$.

We define the linear transformation matrix

$$\mathbf{X} = \{\text{vec}(\mathbf{M}_1), \text{vec}(\mathbf{M}_2), \dots, \text{vec}(\mathbf{M}_N)\}$$

where $\text{vec}(\cdot)$ represents the operator that forms a vector from successive columns of a matrix, and

$$\tilde{\mathbf{H}} = \mathbf{I}_T \otimes \mathbf{H}$$

Let $\mathbf{Y} = \{y_1^T, y_2^T, \dots, y_T^T\}^T$. Then the received signal also can be expressed as

$$\mathbf{Y} = \sqrt{E_s} \tilde{\mathbf{H}} \mathbf{X} \mathbf{s} + \mathbf{v} \quad (4)$$

where $\mathbf{s} = \{s_1, s_2, \dots, s_N\}^T$, $\mathbf{v} = \{\mathbf{v}_1^T, \mathbf{v}_2^T, \dots, \mathbf{v}_N^T\}^T$.

We can see that original $M_r \times M_t$ MIMO system can be regarded as an equivalent $M_r T \times N$ MIMO system. If $M_t T = N$ and \mathbf{X} is a unitary matrix such that $\mathbf{X} \mathbf{X}^H = \frac{1}{M_t} \mathbf{I}$, then such transformation matrix \mathbf{X} is capacity-optimal. The above theorem has been demonstrated in Ref.[7].

2 Proposed Scheme

Fig. 2 shows the diagram of proposed LDCs

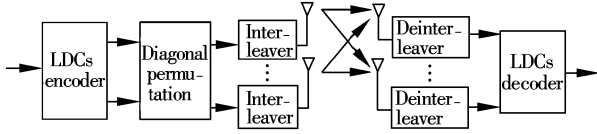


Fig.2 Diagram of the proposed transmission scheme

design. And it can easily be applied to systems with more antennas. We use an M_t transmitting antennas system to describe our design method. Our design will focus on optimal capacity LDCs. This means that $M_t T = N$ ^[7]. Then the transmitted symbols block can be expressed as $\mathbf{s} = \{s_1, s_2, \dots, s_{M_t T}\}^T$. We divide the original block into T sub-blocks, and denote

$$\mathbf{s}_t = \{s_{M_t(t-1)+1}, s_{M_t(t-1)+2}, \dots, s_{M_t t}\}^T \quad 1 \leq t \leq T$$

We encode each sub-block with T different linear transformation matrices. After linear transformation, we obtain

$$\mathbf{s}'_t = \{s'_{t1}, s'_{t2}, \dots, s'_{tM_t}\}^T = \mathbf{A}_t \mathbf{s}_t \quad (5)$$

where $\mathbf{A}_t \in \mathbf{C}^{M_t \times M_t}$, $1 \leq t \leq T$ is the linear transformation matrix of the i -th sub-block. Then we diagonally permute the transmitted symbols at different antennas and time slots. Fig.3 and Fig.4 show examples with two and three transmitting antennas after permutation. Before transmitting over antennas, an interleaver is introduced into each antenna branch. Then at the

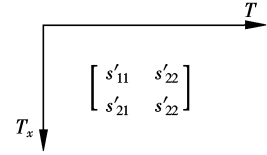


Fig.3 A diagonal permutation example when $M_t = 2$ and $T = 2$

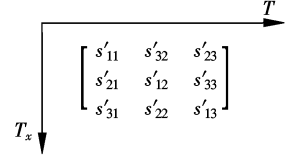


Fig.4 A diagonal permutation example when $M_t = 3$ and $T = 3$

receiver, after deinterleaving, the received signals can be written as

$$\mathbf{Y} = \sqrt{E_s} \tilde{\mathbf{H}} \mathbf{P} \tilde{\mathbf{X}} \mathbf{s} + \mathbf{N} \in \mathbf{C}^{M_r T \times 1} \quad (6)$$

where $\tilde{\mathbf{H}} = \text{diag}(\mathbf{H}_1, \mathbf{H}_2, \dots, \mathbf{H}_T)$ is the channel matrix and \mathbf{H}_i is the $M_r \times M_t$ MIMO channel matrix at the i -th time slot, $\tilde{\mathbf{X}} = \text{diag}(\mathbf{A}_1, \mathbf{A}_2, \dots, \mathbf{A}_T)$ is the linear transformation matrix and \mathbf{P} is the diagonal permutation matrix. In order to design optimal-capacity LDCs, we must let \mathbf{A}_t , $1 \leq t \leq T$ be unitary matrices so that $\mathbf{A}_t \mathbf{A}_t^H = \frac{1}{M_t} \mathbf{I}$. We denote the equivalent

transformation matrix $\tilde{\mathbf{H}} = \mathbf{P} \tilde{\mathbf{X}}$ and the equivalent channel matrix $\tilde{\mathbf{H}} = \tilde{\mathbf{H}} \tilde{\mathbf{X}}$. Then the input-output relation can also be written as

$$\mathbf{y} = \sqrt{E_s} \tilde{\mathbf{H}} \mathbf{s} + \mathbf{N} \quad (7)$$

We apply OSIC detection^[8] to recover transmitted symbols. OSIC detection has considerably low computation complexity compared with maximum likelihood (ML) detection. The pairwise error probability of OSIC detection^[9] can be approximately expressed as

$$P(s \rightarrow e | \tilde{\mathbf{H}}) \approx C \exp \frac{-\Delta^2}{4\sigma^2 \max_i(\mathbf{g}_i^H \mathbf{g}_i)} \quad (8)$$

where C is a constant, Δ represents the minimum distance between any two signal points in the constellation, σ^2 is the noise variance and \mathbf{g}_i is the nulling vector of the i -th detected symbol, $\mathbf{g}_i(\tilde{\mathbf{H}})_j = \delta_{ij}$. Thus our optimization criterion is to find the linear transformation matrix which satisfies

$$\tilde{\mathbf{X}} = \arg \left[\min_{\tilde{\mathbf{X}}} E \{ P(s \rightarrow e | \tilde{\mathbf{H}}) \} \right] \quad (9)$$

We can use computer random search to find the optimized LDCs. For given M_t , T and N , we first generate L matrices $\tilde{\mathbf{X}} = \text{diag}(\mathbf{A}_1, \mathbf{A}_2, \dots, \mathbf{A}_T)$. Then by computer calculation according to Eq.(8), we choose the linear transformation matrix that satisfies Eq.(9) as

the optimized linear dispersion code.

3 Simulations

In this section, we present several optimized LDCs examples. Computer simulations show the performance comparison of our optimized LDCs and LDCs in Refs. [6, 7]. In all simulations, we suggest QPSK modulation and OSIC detection be used.

1) $M_t = M_r = T = 2$, $N = 4$ LDCs

For such a system, our optimized linear dispersion code with equivalent linear transformation matrix \bar{X} is shown as the equation below. The compared LDC is given in Ref. [6].

$$\bar{X} = \begin{bmatrix} -0.0004 + 0.7025i & -0.0537 + 0.0600i & 0 & 0 \\ 0 & 0 & -0.0597 - 0.1773i & 0.4659 + 0.4979i \\ 0 & 0 & -0.4942 - 0.4698i & -0.1768 - 0.0611i \\ -0.0323 - 0.0738i & -0.2188 + 0.6676i & 0 & 0 \end{bmatrix}$$

2) $M_t = M_r = T = 3$, $N = 9$ LDCs

For such a system, our optimized linear dispersion code has equivalent linear transformation matrix

$$\bar{X} = P \text{diag}(A_1, A_2, A_3)$$

where A_1 , A_2 , A_3 are shown as follows. The compared LDC is given in Ref. [7].

$$A_1 = \begin{bmatrix} -0.0573 + 0.5581i & 0.0653 - 0.0551i & 0.0203 - 0.1041i \\ 0.0465 - 0.1060i & 0.0440 - 0.0684i & 0.3021 - 0.4712i \\ -0.0181 - 0.0695i & 0.3405 - 0.4511i & -0.0479 + 0.0805i \end{bmatrix}$$

$$A_2 = \begin{bmatrix} -0.3703 + 0.2719i & 0.2910 - 0.0688i & -0.1673 + 0.0701i \\ -0.2446 - 0.2153i & -0.1805 - 0.4363i & 0.0630 + 0.0145i \\ 0.1234 + 0.0299i & -0.0628 - 0.1305i & -0.4233 - 0.3421i \end{bmatrix}$$

$$A_3 = \begin{bmatrix} -0.2694 - 0.2019i & -0.3224 + 0.3029i & -0.0520 - 0.1471i \\ -0.0181 + 0.0516i & 0.1575 + 0.0019i & 0.2787 - 0.4774i \\ 0.2082 + 0.4167i & -0.3193 + 0.1045i & 0.0314 - 0.0494i \end{bmatrix}$$

Simulation results are given in Fig.5 and Fig.6. Fig.5 and Fig.6 show the system performance with two and three transmit antennas, respectively. Computer simulations show that our optimized LDCs have the best performance compared with the original LDCs in Refs. [6, 7] and normal vertical BLAST (V-BLAST) system.

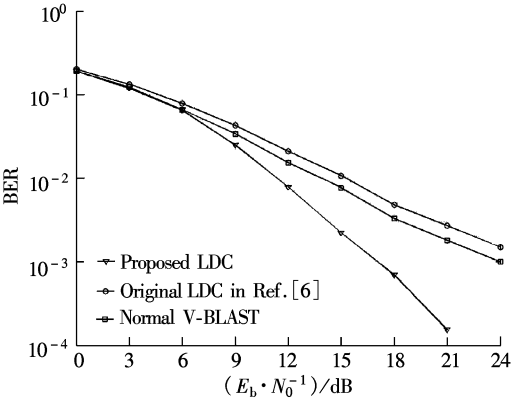


Fig.5 Performance comparison of original and proposed LDCs (2Tx, 2Rx)

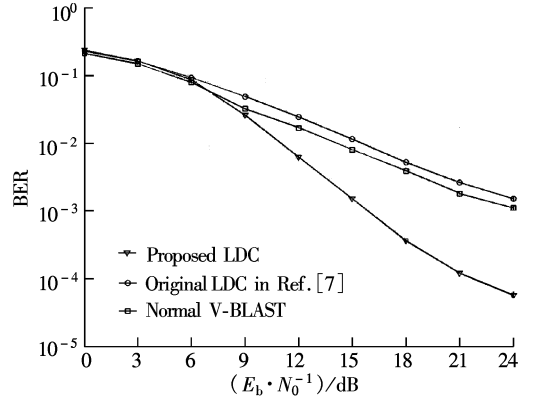


Fig.6 Performance comparison of original and proposed LDCs (3Tx, 3Rx)

4 Conclusion

We propose a novel linear dispersion codes structure. Original LDCs have the weakness that their performance is even worse than normal V-BLAST system for OSIC detection, while our proposed LDCs structure combats such a weakness. Computer simulations demonstrate that our proposed LDCs have better performance than normal V-BLAST and original LDCs.

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基于 OSIC 检测的线性疏散码传输方案

施 风 陈 明 程时昕

(东南大学移动通信国家重点实验室, 南京 210096)

摘要: 最早提出的线性疏散码是基于最大似然检测设计的, 当使用排序的串行干扰抵消(OSIC)检测时并没有好的性能. 本文提出了一种改进的线性疏散码传输方案, 来克服原先的线性疏散码在 OSIC 检测时的性能损失. 在线性疏散码编码器后, 在每个数据支路引入了一个交织器. 此外, 提出了新的线性疏散码传输矩阵计算机搜索准则. 新的搜索准则是最小化 OSIC 检测时的误符号率. 计算机仿真表明, 所提出的线性疏散码传输方案优于原来的线性疏散码.

关键词: 线性疏散码; 空时码; 交织器; 排序的串行干扰抵消检测

中图分类号: TN929