Maximum Diversity Space-Time Systems with Maximum Rate for Any Number of Antennas*

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Abstract

Various multi-antenna designs have been developed in recent years targeting either high-performance, or, high rate. In this paper, we design a layered space-time (ST) scheme equipped with linear complex field (LCF) coding, which enables full diversity with full rate, for any number of transmit- and receive-antennas. Our theoretical claims are confirmed by simulations.

Main Results

Existing multi-antenna designs have been developed targeting either high-performance, or, high rate (e.g., VBLAST [3]). Recently, designs enabling desirable performance-rate tradeoffs receive increasing attention (see e.g., [1]). However, with $N_t(N_r)$ transmit- (receive-)antennae none of these schemes achieves simultaneously full diversity (N_tN_r), and full rate (N_t) for any number of antennas.

In this paper, we design a layered space-time coding (STC) scheme equipped with linear complex field (LCF) coding, which enables full diversity and full rate (FDFR).

System model: The information bearing symbols $\{s(i)\}$ are drawn from a finite alphabet $\mathcal{A}_s$, and parsed into blocks of size $N \times 1$ so that $\boldsymbol{s} := [s(1), \ldots, s(N)]^T$. Every block $\boldsymbol{s}$ is split in sub-blocks (groups) $\{\boldsymbol{s}_g\}_{g=1}^{N_g}$, each of length N_{sub}. Hence, $N = N_{sub}N_g$, where N_g is the number of groups. The LCF encoder $\{\boldsymbol{\Theta}_g\}_{g=1}^{N_g}$ per group is an $N_{sub} \times N_{sub}$ matrix with entries drawn from the complex field. Each sub-block $\boldsymbol{s}_g$ is coded linearly (via $\boldsymbol{\Theta}_g$) to obtain each LCF coded sub-block as: $\boldsymbol{u}_g := \boldsymbol{\Theta}_g \boldsymbol{s}_g$. Define an LCF coded group $\boldsymbol{u}_g$ as one *layer*, and N_g as the number of layers per information block. The layers $\{\boldsymbol{u}_g\}_{g=1}^{N_g}$ are further mapped to space-time matrix $\boldsymbol{C}$, and transmitted through N_t antennas.

Let $h_{\nu,\mu}$ be the Rayleigh independent flat fading channel associated with the μth transmit-antenna, and the νth receive-antenna. Selecting $N_{sub} = N_t$ and $N_g = N_t$, our LCF-ST coded symbols transmitted per time slot from the N_t transmit-antennas are given by:

$$\boldsymbol{C} = \begin{bmatrix} u_1(1) & u_{N_t}(2) & \cdots & u_2(N_t) \\ u_2(1) & u_1(2) & \cdots & u_{N_t-1}(N_t) \\ \vdots & \vdots & \cdots & \vdots \\ u_{N_t}(1) & u_{N_t-1}(2) & \cdots & u_1(N_t) \end{bmatrix}. \tag{1}$$

The matrix input-output relationship is

$$\boldsymbol{Y} = \boldsymbol{H}\boldsymbol{C} + \boldsymbol{W}, \tag{2}$$

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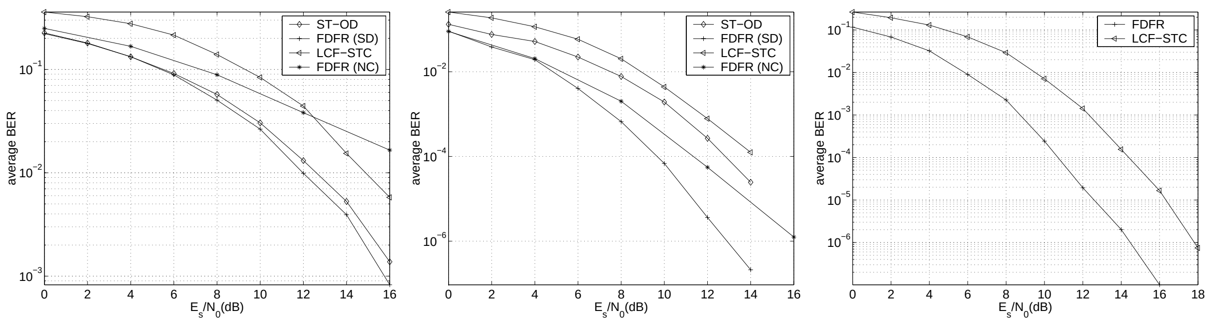
where the (ν, μ)th entry of $\boldsymbol{H}$ is $h_{\nu,\mu}$, and $\boldsymbol{W}$ is additive white Gaussian noise. We establish the following result (see [2] for proofs and detailed derivations):

Proposition: *For any constellation of $\boldsymbol{s}_g$ carved from the Gaussian integer ring $\mathbb{Z}(j)$ (e.g., QAM or PAM), there exists at least one pair of $(\boldsymbol{\Theta}, \beta)$ for which $\boldsymbol{\Theta}_g = \beta^{g-1}\boldsymbol{\Theta}, \forall g \in [1, N_t]$ enable the full diversity $N_t N_r$, and simultaneously full ST transmission rate of N_t symbols per channel use (pcu). The $N_t \times N_t$ matrix $\boldsymbol{\Theta}$ is Vandermonde as in [4] for dimension N_t, and β can be selected as the N_tth root of any generator for $\boldsymbol{\Theta}$. If maximum likelihood (or sphere) decoding is employed at the receiver, then the achieved the diversity order is $N_t N_r$. If nulling-cancelling (NC) decoding is used, then the guaranteed diversity order is $N_r(N_r - N_t + 1)$.*

Simulations: FDFR schemes achieve the same diversity as LCF-STC [4] and space-time orthogonal design (ST-OD), but have better performance because they can afford smaller modulations for the same transmission rate.



(a) $(N_t, N_r) = (2, 2)$
$R = 4$ bits pcu

(b) $(N_t, N_r) = (2, 5)$
$R = 4$ bits pcu

(c) $(N_t, N_r) = (3, 3)$
$R = 3$ bits pcu

Figure 1: Performance comparisons

Tradeoffs: When the transmission rate is fixed, we can sacrifice diversity to lower the decoding complexity by using NC. The interesting case is when we can compromise the rate, to make up for some diversity order. Note that here our performance-rate-complexity tradeoffs are different from the diversity versus rate (capacity) tradeoff in [5]. The rate in [5] is defined as the limit of transmission rate divided by $\log_2$(SNR), as the SNR goes to infinity; while in our approach, we define transmission rate as the number of symbols pcu which takes into account the LCF-ST coding. Unlike [5], our design provides the transceiver design to strike desirable tradeoffs among the performance, transmission rate, and complexity.

References

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