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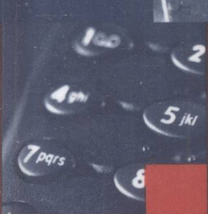

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Preface

The 18th Tyrrhenian Workshop on digital communications is devoted to wireless communications. In the last decade, wireless communications research boosted launching new standards and proposing new techniques for the access technology. We moved from the UTRA standard capable to transmit 0.5 bit/s/Hz to WLAN which is promising 2.7 bit/s/Hz. Now wireless communication systems are facing a flourishing of new proposal moving from multiple antennas at transmitter and receiver side (MIMO systems), to new powerful Forward Error Correction Codes, to adaptive radio resource management algorithms. The new challenge, however, is the move towards multimedia communications and IP technology. This move implies efforts in several new aspects. First of all an open network, as IP is, imposes the necessity of a secure network, to guarantee the privacy of the ongoing communications, avoid the use of the networks by unauthorized customers, avoid the misuses and the charge to third parties of the cost of the connection. Also, quality of service (QoS) of the communications is becoming a must in IP networks which are carrying services which need a guaranteed QoS as telephony, real time services, etc. To get this new target some form of access control to the network must be setup. Recently, new form of communication networks has appeared to collect data for several applications (sensor networks, ad hoc networks, etc.) and they need a connection with a backbone network which could be a wireless one with a larger range than the sensor or ad hoc networks. These new networks are helpful for monitoring applications, and for actuation of some measure to permit a regular use of the available resources. An example could be the use of a road lane in one or opposite direction in different hours of the day as traffic condition requires.

This workshop is trying to put together all these new aspects of wireless communication systems.

It is organized in five sessions entitled: "4G wireless systems", "ad hoc and cellular networks", "security and applications in wireless networks", "QoS and efficiency in multimedia heterogeneous wireless networks", and "wireless sensor networks".

The papers that will be presented represent an up-to-date critical analysis of the state of the art in each of the five areas and they will represent a reference for future development.

As final remarks, we express our gratitude to the session organizers, H. Ogawa, NiCT, Japan; M. Zorzi, University of Padova and CNIT, Italy; A. Prasad, DoCOMO Eurolabs, Germany; A. Jamalipur, University of Sydney, Australia; Shu Kato, NiCT, Japan, which have been in charge of selecting the papers for the workshops.

Also, thanks are to S. Basagni for the publicity action and to T. Erseghe for the hard job of collecting all the papers and checking all the final materials for the preparation of this book.

Shingo Ohmori, NiCT, Japan
Silvano Pupolin, University of Padova and CNIT, Italy
Workshop Co-Chairs

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Session 1

4G Wireless Systems

Spatial Detection and Multistage Decoding for LST-MLC MIMO Systems

Maurizio Magarini and Arnaldo Spalvieri

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Summary. Layered space–time (LST) coding schemes based on multilevel coding (MLC) represent a good approach to achieve high bandwidth and power efficiency in wireless transmission over multiple-input multiple-output (MIMO) channels. The combination of spatial detection algorithms and multistage decoding (MSD) is required at the receiver to perform soft detection and decoding. Since the complexity of the soft detection and decoding process may be impractical for many systems, we are interested in developing low complexity schemes providing a good tradeoff between performance and complexity. In this paper we compare the performance of two different LST-MLC architectures where MSD at the receiver is combined with different suboptimal spatial detection techniques.

Key words: MIMO systems, Layered space–time coding, Multilevel coding, Multistage decoding

1 Introduction

The ever increasing demand for high bandwidth and/or power efficiency in wireless communications leads to the introduction of architectures based on multiple antenna elements both at the transmitter and at the receiver [1]. Layered space–time (LST) coding schemes based on multilevel coding (MLC) is a suitable approach to achieve these expected efficiency benefits [2–5]. MLC, introduced in [6] together with the concept of multistage decoding (MSD), represents the optimum capacity achieving approach when the separation of coding and modulation is considered in single-input single-output systems [7]. In [2] it is shown that MLC also constitutes the optimum coded modulation scheme for transmission over multiple-input multiple-output (MIMO) channels when multiple-antenna signaling is regarded as multidimensional modulation.

The combination of MLC and LST can be realized in the same way as conventional block or convolutional coding is introduced in an LST transmission scheme [1]. Among such architectures, the horizontal LST (HLST) approach has the advantage of being easily incorporated into existing systems and rendering the implementation of the decoding process at the receiver less complex. Depending on the position of the multilevel encoder in the transmitter chain, there are two alternative approaches to implement an HLST-MLC architecture. With the first, proposed in [2] and called here separate HLST-MLC (S-HLST-MLC), the information sequence is demultiplexed in n_T substreams which are separately encoded by n_T multilevel encoders. Although a multidimensional mapping might be applied, for a practical implementation blocks of bits at the output of each multilevel encoder are mapped according to their significance to one constituent PSK/QAM symbol. In contrast to [2], where code rates of the component encoders are chosen according to the constellation-constrained capacity at each level, we consider the case where identical multilevel encoders are used on the separate transmit antenna branches. In the second approach, called joint HLST-MLC (J-HLST-MLC), the information sequence is encoded by the same multilevel encoder used on the separate branches of S-HLST-MLC scheme. Coded bits at the same level are then demultiplexed in n_T substreams and mapped, according to their significance, to the constituent PSK/QAM symbols transmitted over the n_T transmit antenna elements.

The signal at the receiving antenna elements consists of a spatial superposition of the transmitted multilevel encoded symbols scaled by the fading coefficients and corrupted by additive white Gaussian noise. Spatial detection techniques combined with MSD are required at the receiver to perform soft detection and decoding. Since the complexity of the soft detection and decoding process may be impractical for many systems, we are interested in developing low complexity receiving schemes providing a good tradeoff between performance and complexity. In particular, we will compare the performance of the two HLST-MLC schemes where the reduction of the complexity of the soft detection-decoding process is achieved through the use of different suboptimal low-complexity spatial detection algorithms.

The spatial detection stage is responsible for generating the soft information to be passed to the MSD. The optimum spatial detector, which is the maximum likelihood detector (MLD), has a complexity proportional to M^{n_T}, where M denotes the number of points of the PSK/QAM constellation. The complexity of the MLD can be prohibitively large when the number of transmitting antennas and constellation points is high. The receiver architecture proposed in [10] for an uncoded LST system, also known as vertical Bell Layered Space–Time (V-BLAST) detector, is a practical nonlinear detection technique that allows the detection of the n_T substreams while keeping the complexity low. In such a scheme symbols are detected sequentially according to the well known ordered successive interference suppression and cancellation process (OSIC). Despite its detection simplicity, the main drawback of the V-BLAST approach is that the diversity order in the early stages is lower than in the next ones. This contributes to enhancing the performance gap between V-BLAST and MLD (in the latter the diversity order is equal to n_T).

Several sub-optimal detection strategies can be devised to reduce the performance gap. In particular, we are interested in the performance obtained when the detection is done by using the V-BLAST coset detector (V-BLAST-CD) of [8]. The V-BLAST-CD is obtained by extending the principle of reduced state sequence estimation [9], based on mapping by set partitioning (MSP), to perform the detection in LST transmission systems using non-binary constellations. In [8] it is shown that the V-BLAST-CD greatly outperforms the conventional V-BLAST detector at the cost of a slight increase of complexity. In particular, from low-to-intermediate signal-to-noise ratio (SNR) the performance of the V-BLAST-CD is the same as that of MLD, while at high SNR the V-BLAST-CD still provides a significant performance gain over the V-BLAST detector.

The paper is organized as follows. The model of the MIMO system we focus on is given in Sect. 2. Section 3 introduces the two HLST-MLC schemes we have considered throughout the paper. In Sect. 4 we illustrate the two LST-MSD receivers implementing detection and decoding of the information bits transmitted by using the two HLST-MLC schemes. A description of the suboptimal low-complexity spatial detection algorithms and the associated soft metric computations we have used in the LST-MSD receivers is given in Sect. 5. Experimental results are then shown in Sect. 6 and conclusions are drawn in Sect. 7.

2 System Model

We consider the equivalent discrete-time complex-baseband representation of a flat fading MIMO channel with n_T transmitting antennas and $n_R \geq n_T$ receiving antennas. The received signal vector at k-th time instant is

$$\mathbf{r}_k = \mathbf{H}_k \mathbf{x}_k + \mathbf{n}_k, \tag{1}$$

where $\mathbf{x}_k$ is the $n_T \times 1$ vector of transmitted complex symbols drawn from a square M-QAM constellation, $\mathbf{n}_k$ is the $n_R \times 1$ noise vector whose entries are temporally and spatially i.i.d. complex Gaussian random variables (RVs) with zero mean and variance σ_n^2 and $\mathbf{H}_k$ is the $n_R \times n_T$ channel matrix whose elements are spatially i.i.d. RVs having uniform-distributed phase and Rayleigh-distributed magnitude with average power equal to 1. $\mathbf{H}_k$ is independent of both $\mathbf{x}_k$ and $\mathbf{n}_k$ and it is assumed perfectly known to the receiver. We assume a block-fading channel, where $\mathbf{H}_k$ assumes a constant value over a coded symbol frame and then changes to a new value. The average radiated power from each antenna is fixed to $1/n_T$. Thus, the total average radiated power is fixed to 1 and it turns out to be independent of the total number of transmitting antennas. The average SNR per transmitted symbol at the receiver is defined as $\mathrm{SNR} = n_R/(n_T \sigma_n^2)$.

3 HLST-MLC Transmission Schemes

A description of the two HLST-MLC transmission schemes we focus on throughout the paper is given in Sects. 3.1 and 3.2.

3.1 S-HLST-MLC

In the S-HLST-MLC scheme the input information sequence is demultiplexed into n_T substreams which are separately multilevel encoded, modulated by an M-QAM modulator and transmitted in parallel from n_T antennas at the same time and frequency. Each substream in turn is demultiplexed in $m = 1/2 \cdot \log_2 M$ parallel sequences which are distributed to the component encoders according to their relative rate. The modulator uses mapping by set partitioning, where a binary partition is considered at each partitioning level for each dimension of the QAM constellation. Let $\{b_{\Re;m}, \ldots, b_{\Re;1}\}$ and $\{b_{\Im;m}, \ldots, b_{\Im;1}\}$ be, respectively, the binary labels for the real part, $x_{\Re}$, and the imaginary part, $x_{\Im}$, of the QAM constellation symbols x. Bits are listed from the most (MSB, first entry with index m) to the least significant (LSB, last entry with index 1). The block diagram of the S-HLST-MLC scheme is shown in Fig. 1. We assume that MLC on the separate branches uses identical component codes at the same partitioning level.

3.2 J-HLST-MLC

In contrast to S-HLST-MLC, in the J-HLST-MLC transmission scheme the input information sequence is encoded by using only one multilevel encoder.

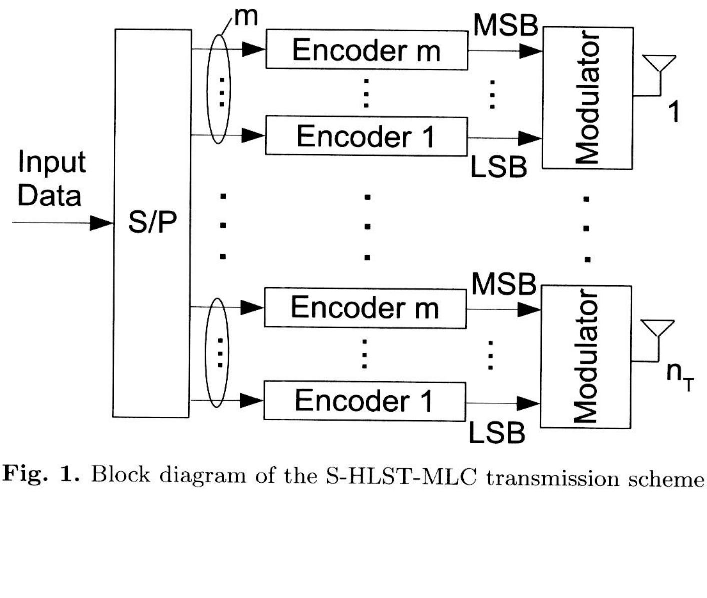

Fig. 1. Block diagram of the S-HLST-MLC transmission scheme