Chapter VIII
Blind Channel Estimation in Space-Time Block Coded Systems

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ABSTRACT

This chapter analyzes the problem of blind channel estimation under Space-Time Block Coded transmissions. In particular, a new blind channel estimation technique for a general class of space-time block codes is proposed. The method is solely based on the second-order statistics of the observations, and its computational complexity reduces to the extraction of the main eigenvector of a generalized eigenvalue problem. Additionally, the identifiability conditions associated to the blind channel estimation problem are analyzed, which is exploited to propose a new transmission technique based on the idea of code diversity or combination of different codes. This technique resolves the ambiguities in most of the practical cases, and it can be reduced to a non-redundant precoding consisting in a single set of rotations or permutations of the transmit antennas. Finally, the performance of the proposed techniques is illustrated by means of several simulation examples.

INTRODUCTION

In the last ten years, since the well known work of Alamouti (1998), and the later generalization by Tarokh et al. (1999), space-time block coding (STBC) has emerged as a promising technique to exploit the spatial diversity in multiple-input multiple-output (MIMO) communication systems. A common assumption for most of the STBCs is that perfect channel state information (CSI) is available at the receiver, which has motivated an increasing interest in blind techniques (Ammar & Ding, 2006, 2007, Larsson et al., 2003; Ma et al., 2006; Shahbazpanahi et al., 2006; Stoica & Ganesan, 2003; Swindlehurst & Leus, 2002). The main advantage of blind approaches resides in their ability to avoid the penalty in bandwidth efficiency or signal to noise ratio (SNR) associated, respectively, to training based techniques (Hassibi & Hochwald, 2003; Naguib et al., 1998; Pohl et al., 2005), or differential schemes (Ganesan & Stoica, 2002; Hochwald & Sweldens, 2000; Hughes, 2000; Jafarkhani & Tarokh, 2001; Tarokh & Jafarkhani, 2000; Zhu & Jafarkhani, 2005). On the other hand, these advantages come at the cost of an increase in both computational complexity and latency, which can be seen as a direct consequence of the common assumption about the coherence time of the MIMO channel.

Blind channel estimation or blind decoding techniques can be divided into two groups depending on whether they exploit the higher-order statistics (HOS) or the second-order statistics (SOS) of the signals. The main advantage of SOS-based approaches consists in their reduced computational complexity and independency of the specific signal constellation. Unfortunately, most of the blind techniques have been proposed for the particular case of orthogonal STBCs (OSTBCs) (Ammar & Ding, 2006; Larsson et al., 2003; Ma et al., 2006; Shahbazpanahi et al., 2006; Stoica & Ganesan, 2003), and the number of methods for more general settings is rather scarce (Shahbazpanahi et al., 2006; Swindlehurst, 2002; Swindlehurst & Leus, 2002). Furthermore, it can be easily proven that some of these techniques are affected by additional indeterminacies to those associated to the blind channel estimation problem.

In this chapter, the blind channel estimation problem is formulated for a general class of STBCs, and a new SOS-based technique is proposed. The method reduces to the extraction of the main eigenvector of a generalized eigenvalue problem (GEV), it does not introduce additional indeterminacies to those of the blind channel estimation problem, and it can be easily extended to multiuser settings. Additionally, we provide an identifiability analysis for the general STBC case, where some intuitive necessary conditions are obtained, and in the particular OSTBC case, we present several sufficient conditions for blind channel identifiability, which shed some light into previous numerical results obtained by other authors. Finally, we propose several techniques for the solution of the indeterminacies. On one hand, in the OSTBC case the ambiguities can be easily avoided by exploiting the HOS, the correlation properties of the sources, or by slightly reducing the transmission rate. On the other hand, we propose a new technique for the general STBC case. The proposed method is based on the general idea of code diversity, which consists in combining different STBCs. However, it can be reduced to a non-redundant precoding consisting in a single rotation or permutation of the transmit antennas, which comes at virtually no computational expense at the transmitter. Unlike previous approaches, the code diversity technique is able to avoid the ambiguities in most of the cases without any penalty in terms of transmission rate nor capacity.

The structure of this chapter is as follows: The STBC data model and some code examples are introduced in Section 2. A brief review of some previously proposed blind channel estimation techniques is presented in Section 3. In Section 4 the new blind channel estimation criterion is presented, and in Section 5 the identifiability conditions are analyzed. In Section 6 we propose several techniques for the solution of the ambiguities. Finally, the performance of the proposed techniques is illustrated in Section 7 by means of several simulation examples, and the main conclusions are summarized in Section 8.

SPACE-TIME BLOCK CODING DATA MODEL

Notation

Throughout this chapter we will use bold-faced upper case letters to denote matrices, e.g., $\mathbf{X}$ with elements $x_{i,j}$; bold-faced lower case letters for column vector, e.g., $\mathbf{x}$, and light-faced lower case letters for scalar quantities. The superscripts $(\cdot)^T$, $(\cdot)^H$ and $(\cdot)^*$ denote transpose, Hermitian and complex conjugate, respectively. The real and imaginary parts will be denoted as $\Re(\cdot)$ and $\Im(\cdot)$, and superscript $\hat{(\cdot)}$ will denote estimated matrices, vectors or scalars. The trace, range (or column space) and Frobenius norm of matrix $\mathbf{A}$ will be denoted as Tr($\mathbf{A}$), range($\mathbf{A}$) and $\|\mathbf{A}\|$, respectively. Finally, the identity and zero matrices of the required dimensions will be denoted as $\mathbf{I}$ and $\mathbf{0}$, $E[\cdot]$ will denote the expectation operator, and $\lceil q \rceil$ will denote the smallest integer greater or equal than q.

We will consider a flat fading MIMO system with n_T transmit and n_R receive antennas. The $n_T \times n_R$ complex channel matrix is

$$\mathbf{H} = \left[\mathbf{h}_1 \cdots \mathbf{h}_{n_R}\right] = \begin{bmatrix} h_{1,1} & \cdots & h_{1,n_R} \\ \vdots & \ddots & \vdots \\ h_{n_T,1} & \cdots & h_{n_T,n_R} \end{bmatrix},$$

where $h_{i,j}$ denotes the channel response between the i-th transmit and the j-th receive antennas, and $\mathbf{h}_j$ contains the channel

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