Chapter 6
Implementation Strategies for High-Performance Multiuser MIMO Precoders

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ABSTRACT

The multiuser MIMO environment enables the communication between a base-station and multiple users with several antennas. In such a scenario, the use of precoding techniques is required in order to detect the signal at the users' terminals without any cooperation between them. This contribution presents various designs and hardware implementations of a high-capacity precoder based on vector perturbation. To this aim, three tree-search techniques and their associated user-ordering schemes are investigated in this chapter: the well-known K-Best precoder, the fixed-complexity Fixed Sphere Encoder (FSE), and the variable complexity Single Best-Node Expansion (SBE). All of the aforementioned techniques aim at finding the most suitable perturbation vector within an infinite lattice without the high computational complexity of an exhaustive search.

INTRODUCTION

The demand for high-speed communications required by cutting-edge applications has put a strain on the already saturated wireless spectrum. The incorporation of antenna arrays at both ends of the communication link has provided improved spectral efficiency and link reliability to the inherently complex wireless environment, thus allowing for the thriving of high data-rate applications without the cost of extra bandwidth consumption. As a consequence to this, multiple-input multiple-output (MIMO) systems have become the key technology for wideband communication standards both in single-user and multi-user setups.

The main difficulty in single-user MIMO systems stems from the signal detection stage at the receiver, whereas multi-user downlink...
systems struggle with the challenge of enabling non-cooperative signal acquisition at the user terminals. In this respect, precoding techniques perform a pre-equalization stage at the base station so that the signal at each receiver can be interpreted independently and without the knowledge of the overall channel state. The non-linear vector precoding (VP) technique has been proven to enable non-cooperative signal acquisition in the multi-user broadcast channel with a feasible complexity (Hochwald, Peel, Swindlehurst, 2005). The performance advantage with respect to the more straightforward linear precoding algorithms is the result of an added perturbation vector which enhances the properties of the precoded signal. Nevertheless, the computation of the perturbation signal entails a search for the closest point in an infinite lattice, which is known to be in the class of non-deterministic polynomial-time hard (NP-hard) problems.

This chapter addresses the difficulties that stem from the perturbation process in VP systems from a hardware implementation perspective. This study is focused on tree-search techniques that, by means of a strategic node pruning policy, reduce the complexity derived from an exhaustive search and yield a close-to-optimum error-rate performance. In the last section of the chapter, the incorporation of alternative norms in the distance computation process will be analyzed, which can greatly reduce the computational cost of all the reviewed tree-search schemes.

**BACKGROUND**

With the advent of new communication technologies, the interest in MIMO has recently evolved towards the development of multi-user schemes which consider more complex albeit realistic scenarios with multiple terminals sharing the time, space, bandwidth and power resources available in a wireless network. Consequently, a great part of the latest research on innovative wireless multi-antenna technologies has been focused on multi-user MIMO (MU-MIMO) environments.

A multi-antenna and multi-user system provides a set of advantages over point-to-point MIMO transmissions. One of the main features of MU-MIMO is its greater immunity to propagation shortcomings derived from antenna correlation. Being the antennas hosted at scattered users, the correlation coefficients are inherently low, which allows to overcome the usual problems related to channel rank loss. Another interesting property of MU-MIMO is that direct line of sight propagation, which greatly degrades the quality of the communication link in single-user MIMO systems with spatial multiplexing, does not pose a problem in a multi-user setup. Furthermore, MU-MIMO enables obtaining a spatial multiplexing gain at the base station without the requirement of multi-antenna receivers. This allows for the implementation of small, low-cost and low-power terminal devices as the computational load is transferred to the base station (Gesbert, Kountouris, Heath & Chae, 2007).

Nevertheless, the multi-user setup also poses a set of problems that do not exist in the single-user model. For example, the lack of interaction between the users forces the base station to acquire instantaneous knowledge of the channel in order to allow for independent detection of each user’s information stream at the receivers. Additionally, the independence between the receive antennas may also incur in an outage situation if the sub-channel directed to a single-antenna user undergoes severe fading. Such a situation in MIMO systems can be overcome with simple diversity techniques.

Generally speaking, the multi-user MIMO environment is composed of two channels that communicate the base station with the user terminals: the multiple access channel (MAC), also known as the uplink channel, covers the communication from the terminals to the base station, whereas the broadcast channel (BC), or downlink channel, carries the transmissions that stem from the base