Improved Detection Algorithms of Space-Time Block Codes Using QR-Decomposition

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Abstract

In this paper, we first apply PD and p-PD algorithms to STBCs. The PD algorithm is approximately 1 to 2 dB inferior to ML detection at a SER of 10^{-3} and the p-PD algorithm with $p = 2$ offers performance virtually identical to that of the ML detection. Also, based on the algorithms, we propose two improvements which offer performance virtually identical to that of the PD and p-PD algorithms for 4 transmit antennas with approximately 1/5 to 4/5 the complexity of them for moderate modulation order.

I. Introduction

Practical multiple antenna transmission schemes are generally classified into spatial multiplexing and/or space-time coding [1]. Spatial multiplexing such as the Vertical Bell Labs Layered Space-Time (V-BLAST) scheme is a transmission scheme where independent data signals are simultaneously transmitted over distinct transmit antennas. In V-BLAST systems, the QR decomposition of the equivalent space-time channel matrix has proved successful [2]-[3] and algorithms, such as decision feedback (DF) [2], parallel detection (PD) [3] and p-PD [11], [14] have been developed. The DF algorithm [2], based on the concept of interference nulling and cancellation is very simple but suffers severe performance losses due to error propagation. The PD algorithm [3] improves on the DF algorithm by first choosing a layer called the candidate layer and applying the DF algorithm to the remaining layers for each of the candidate symbols in the candidate layer. The final decision is made by minimizing the Euclidean distance between the received vector and the candidate N-tuples where N is the number of transmit antennas. The p-PD algorithm [11], [14] is a direct extension of the PD algorithm where $p \geq 2$ candidate layers are used instead of just one. The PD and p-PD algorithms, at least up to 4 transmit antennas, seem to offer the best performance/complexity trade-off with ML approaching performance and reasonable complexity.

Space-time coding, on the other hand, is a coding technique appropriate for multiple transmit antennas with the main objective of obtaining spatial diversity [4]-[7]. Coding is performed across the spatial dimension as well as time in order to achieve spatial diversity and coding advantages over multipath fading channels. Alamouti in [6], proposed a scheme using two transmit antennas which achieves full spatial diversity for any complex modulation and allows simple ML detection at the receiver. Tarokh *et al.* in [7], generalized Alamouti's scheme and developed orthogonal space-time block codes (O-STBCs) based on the theory of orthogonal designs achieving full spatial diversity and allowing simple ML detection due to their inherent orthogonality. Unfortunately, full-rate O-STBCs supporting more than two transmit antennas do not exist when used with general QAM [6], [7]. Without additional structure, the ML detection complexity for general STBCs using Q-ary QAM modulation with N transmit and M receive antennas is proportional to MQ^N which quickly becomes impractical as N and/or Q increases. Unlike V-BLAST schemes where much of the effort has been focused on developing efficient suboptimal detectors, most of the previous works on STBCs focus on ML detection.

Recently, an attempt was made to apply the DF algorithm to the detection of STBCs which resulted in severe performance losses over ML detection [8]. In order to achieve ML approaching performance with reasonable complexity, a sphere decoding technique [15] was applied to the detection of STBCs [15], [19], [20]. Using the scheme proposed in [15], the sphere decoding algorithm achieves ML approaching performance with decoding complexity on the order of $(2N)^6$ [15], [20]. The main design issue in sphere decoding algorithms is the choice of the initial sphere radius which is sensitive to channel parameters such as the signal-to-noise ratio (SNR) [15], [16]. Clearly, other simple V-BLAST detection algorithms, such as PD and p-PD algorithms can also be applied to space-time block coded systems possessing equivalent space-time channel matrices. In this paper, we first apply PD and p-PD algorithms to STBCs. The PD algorithm is approximately 1 to 2 dB inferior to ML detection at an average symbol error rate (SER) of 10^{-3} and the p-PD algorithm with $p = 2$ offers performance virtually identical to that of the ML detection. Also, we propose improvements with low complexity based on the algorithms. Two proposed algorithms offer performance virtually identical to that of the PD and p-PD algorithms for 4 transmit antennas with approximately 1/5 to

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