

## Foreword

Owing to their ability to multiply wireless capacity, mitigate slow fading, and facilitate new adaptive communications beyond the limits of conventional single-antenna wireless systems, MIMO and Space Time Coding techniques (which combine coding, modulation and signal processing designs in systems employing multiple transmit/receive antennas) have generated much research interest in recent years. Their adoption in cellular mobile radio, wireless LAN and wireless MAN standards have also marked their increasing significance in commercial broadband wireless systems.

An important class of space-time code is the Orthogonal Space-Time Block Code (O-STBC), which is attractive for its low decoding complexity, low decoding latency, and ability to provide full transmit diversity for mitigating slow fading by requiring multiple antennas only at the base stations or access points (hence low cost per user). However O-STBC suffers from low code rate (hence non-optimal MIMO capacity) when used with more than 2 transmit antennas and complex modulation. This rate disadvantage can be alleviated by a class of group-decodable STBC design called the Quasi-Orthogonal STBC (QO-STBC). The decoding complexity of QO-STBC is higher than that of O-STBC, but it can be capped by proper code design.

This monograph focuses on the design and analysis of full-diversity QO-STBC with very low decoding complexity and high code rate. Much of the monograph is dedicated to double-symbol-decodable QO-STBC and single-symbol-decodable QO-STBC, which have the two lowest levels of decoding complexity among all QO-STBC. Apart from coherent code detection, differential space-time modulation designs for the non-coherent (blind) detection of double- and single-symbol-decodable QO-STBC are also presented. The latter part of this monograph shifts the design focus away from minimum decoding

complexity to constant full rate (i.e. code rate = 1) for arbitrary number of transmit antennas, and finally to code rate  $> 1$ .

Chapter 1 of the monograph sets out the essential foundations for subsequent technical discussions. They include the MIMO channel model, the dispersion matrix representation of QO-STBC, the concept of equivalent channel matrix, as well as the code parameters, performance measures, and the well-known *Rank and Determinant* design criteria of QO-STBC. Chapter 2 reviews the state of the arts in O-STBC and QO-STBC, and compares their essential differences in code rate, decoding complexity and number of antennas supported. The classical Amicable Orthogonal Design (AOD) for constructing O-STBC and constellation rotation (CR) technique for rendering full diversity in QO-STBC are also discussed. Chapter 3 elaborates on the concept of group-wise symbol decoding that gives QO-STBC its low decoding complexity advantage. The constraints required of the QO-STBC dispersion matrices to render it group-decodable are derived. They are shown to lead to the unexpected finding that the classical CR technique applied on many past QO-STBC actually leads to increased decoding complexity for the resultant codes. Hence an alternative constellation transformation technique, called Group-Constrained Linear Transformation (GCLT), is presented to resolve this issue. Chapter 4 moves the low decoding complexity code design attempt a step further by introducing a class of single-symbol-decodable QO-STBC called Minimum Decoding Complexity QO-STBC (MDC-QOSTBC), which has the lowest possible decoding complexity among any QO-STBC. Its dispersion matrix constraints, code construction rules, optimum code parameters, code performance, and antenna downscaling methods are discussed in depth. A new AOD concept called Preferred AOD Pair (developed from the classical AOD discussed in Chapter 2) is also presented to derive the maximum achievable code rates of MDC-QOSTBC for any given number of transmit antennas. In Chapter 5 we switch our focus to the design of non-coherent detection for QO-STBC with low decoding complexity. In contrast to existing works, we obtain non-coherent QO-STBC by designing special “joint constellation” sets for the double- and single-symbol-decodable QO-STBC (discussed in Chapter 3 and 4) to achieve certain unitary or quasi-unitary code structure without affecting the

quasi-orthogonality of the code. To our knowledge, the single-symbol-decodable non-coherent QO-STBC pioneered by us was the first and remained the lowest decoding complexity design with higher code rate than non-coherent O-STBC. In Chapter 6 we move the code design emphasis away from low decoding complexity to flexible rate codes. Two new classes of STBC are presented: constant full-rate QO-STBC with 4 separately-decodable symbol groups for arbitrary number of transmit antennas, and QO-STBC with code rate  $> 1$ . The code search methodology of the latter is based on an interesting application of the QO-STBC code constraints derived in Chapter 3 into the classical graph theory and tree search algorithms. Among the new codes found are the first-ever QO-STBC's with code rate of  $5/4$  for 4 transmit antennas. Finally, in Chapter 7 we outline the potential roles of QO-STBC in large-scale communication systems with hybrid ARQ, FEC, super space-time trellis coding or MIMO OFDM, as well as in commercial wireless standards such as 3GPP LTE.

We thank the Imperial College Press for initiating this monograph idea. We hope that the monograph will give the readers a comprehensive and integrated picture of the many recent advances in this interesting class of space-time code, and spur further innovations to unlock the full potential of MIMO communication for realizing mankind's dream of the Wireless Utopia.

*Chau Yuen*  
*Yong Liang Guan*  
*Tjeng Thiang Tjhung*