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Complex Orthogonal Space-Time Processing in Wireless Communications

Springer

COMPLEX O SPACE-TIME PROCESSING IN WIRELESS COMMUNICATIONS

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Foreword

Multiple-Input Multiple-Output (MIMO) systems have recently been the subject of intensive consideration in modern wireless communications as they offer the potential of providing high capacity, thus unleashing a wide range of applications in the wireless domain. The main feature of MIMO systems is the use of space-time processing and Space-Time Codes (STCs). Among a variety of STCs, orthogonal Space-Time Block Codes (STBCs) have a much simpler decoding method, compared to other STCs.

This book provides an in depth understanding of space-time processing in general and space-time block processing in particular including their applications in MIMO wireless communication systems. Importantly, the book provides readers, for the first time, with state of the art critical reviews and findings in the area of space-time processing. The authors' latest discoveries in the field of complex orthogonal space-time processing for wireless communications represent the core contributions of the book along an overview of open research issues.

This book is considered suitable for both general and professional audiences in the areas of Communications, Vehicular Technology, Signal Processing, and to some extent Information Theory. In many ways, it can be considered as a supplementary text for the standard courses in advanced wireless communications as well as a fundamental source of knowledge for future research in the area of orthogonal space-time processing.

One anticipates that this book will provide lasting values for both research and educational purposes.

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Preface

Digital communication using Multiple-Input Multiple-Output (MIMO) systems has recently emerged as one of the most significant technical breakthroughs in modern communication. Communication theories show that MIMO systems can potentially provide potentially a very high capacity that, in many cases, grows approximately linear with the number of antennas. Therefore, MIMO transmission is an outstanding technique with a chance to resolve the bottleneck of traffic capacity in the future wireless networks.

The main feature of MIMO systems is *space-time* processing. Space-Time Codes (STCs) are the codes designed for the use in MIMO systems. Among a variety of STCs, *orthogonal* Space-Time Block Codes (STBCs) possess a much simpler decoding method over other STCs. Because of that, this book examines *orthogonal* STBCs in MIMO systems. Furthermore, Complex Orthogonal STBCs (CO STBCs) are *mainly* considered in this book since they can be used for PSK/QAM modulation schemes, and therefore, are more practical than real STBCs.

The book starts with the backgrounds on MIMO systems and their capacity, on STBCs, and on some conventional transmission diversity techniques. After reviewing the state of the art of the issues related to this book and indicating the gaps in the literature, we mention the following topics:

Novel constructions methods for improved, square CO STBCs

In this book, we first propose three new, *maximum rate*, order-8 CO STBCs. These new CO STBCs are amenable to practical implementations as they allow for a more uniform spread of power among the transmitter antennas, while providing better performance than other published codes of order 8 for the same peak power per transmitter antenna.

Constructions of *square, maximum rate* CO STBCs are well known, however codes constructed via the known methods include numerous zeros, which impede their practical implementation, especially in high data rate systems. This disadvantage is partially overcome by the three new CO STBCs of order 8 mentioned above. However, these new codes still contain zeros which are undesirable or the design method is *neither* general *nor* easy yet.

Hence, later, we discover two construction methods of *square*, order-$4n$ CO STBCs from *square*, order-n codes which satisfy certain properties, by modifying the Williamson and the Wallis-Whiteman arrays to apply to complex matrices. Applying the proposed methods, we construct *square*, *maximum rate*, order-8 CO STBCs with no zeros, such that the transmitted symbols equally disperse through transmitter antennas. Those codes, referred to as the *improved square CO STBCs*, have the advantages that the power is equally transmitted via each transmitter antenna during every symbol time slot and that a lower peak power per transmitter antenna is required to achieve the same bit error rates as in the conventional CO STBCs with zeros.

Multi-modulation schemes to increase the data rate of CO STBCs

Based on the new proposed CO STBCs, multi-modulation schemes (MMSs) are proposed to increase the information transmission rate of those new codes of order 8. Simulation results show that, for the same MMSs and the same peak power per transmitter antenna, the three new codes provide better error performance than the conventional CO STBCs of the same order 8.

In addition, the method to evaluate the optimal inter-symbol power allocation in the proposed codes in single modulation as well as in different MMSs for both Additive White Gaussian Noise (AWGN) and flat Rayleigh fading channels is derived. It turns out that, for some modulation schemes, equal power transmission per symbol time slot is not only optimal from the technical point of view, but also optimal in terms of achieving the best symbol error probability.

The MMSs which increase the information transmission rate of CO STBCs and the method to examine the optimal power allocation for multi-modulated CO STBCs mentioned here can be generalized for CO STBCs of other orders without any difficulty.

Transmitter diversity antenna selection techniques for MIMO systems using STBCs and DSTBCs

The combination of CO STBCs and a closed loop transmission diversity technique using a feedback loop has received a considerable attention in the literature since it allows us to improve performance of wireless communication channels with coherent detection. In this book, we propose an improved diversity Antenna Selection Technique (AST) to improve further the performance of such channels. Calculations and simulations show that our technique performs well, especially, when it is combined with the Alamouti code.

While the combination between STBCs and a closed loop transmission diversity technique in the case of *coherent detection* has been intensively considered in the literature, it seems to be missing for the case of *differential detection.* The book thus proposes two ASTs for wireless channels utilizing Differential Space-Time Block Codes (DSTBCs), which are referred to as the AST/DSTBC schemes. These techniques remarkably improve the performance of wireless channels using DSTBCs (with *differential detection*).

Effects of imperfect channels on transmitter diversity antenna selection techniques

The proposed AST/DSTBC schemes work very well in independent, flat Rayleigh fading channels as well as in the case of perfect carrier recovery. How do they perform in the case of correlated, flat Rayleigh fading channels or in the case of imperfect carrier recovery?

To answer this question, first, we propose here a very general, straightforward algorithm for the generation of an *arbitrary number* of Rayleigh envelopes with any desired (*equal* or *unequal*) power, in wireless channels either *with* or *without* Doppler frequency shift effects. The proposed algorithm can be applied to the case of *spatial correlation*, such as with antenna arrays in Multiple Input Multiple Output (MIMO) systems, or *spectral correlation* between the random processes like in Orthogonal Frequency Division Multiplexing (OFDM) systems. It can also be used for generating correlated Rayleigh fading envelopes in either *discrete-time instants* or a *real-time scenario.* Besides being *more generalized*, our proposed algorithm is *more precise*, while overcoming all shortcomings of the conventional methods.

Based on the proposed algorithm for generating correlated Rayleigh fading envelopes, the performance of our AST/DSTBC techniques proposed for systems utilizing DSTBCs in spatially correlated, flat Rayleigh fading channels is analyzed. Finally, the book examines the effect of imperfect carrier phase/frequency recovery at the receiver on the bit error performance of our AST/DSTBC schemes proposed for channels utilizing DSTBCs. The tolerance of differential detection associated with the proposed ASTs to phase/frequency errors is then analyzed. These analyses show that our ASTs not only work well in independent, flat Rayleigh fading channels as well as in the case of perfect carrier recovery, but also are very robust in correlated, flat Rayleigh fading channels as well as in the case of imperfect carrier recovery.

The book is concluded with recommendations on the issues examined here and with a number of future research directions.

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