Space–Time Block Coding for Wireless Communications: Performance Results

Vahid Tarokh, *Member, IEEE*, Hamid Jafarkhani, *Member, IEEE*, and A. Robert Calderbank, *Fellow, IEEE*

Abstract—We document the performance of space–time block codes [13], [14], which provide a new paradigm for transmission over Rayleigh fading channels using multiple transmit antennas. Data is encoded using a space–time block code, and the encoded data is split into n streams which are simultaneously transmitted using n transmit antennas. The received signal at each receive antenna is a linear superposition of the n transmitted signals perturbed by noise. Maximum likelihood decoding is achieved in a simple way through decoupling of the signals transmitted from different antennas rather than joint detection. This uses the orthogonal structure of the space–time block code and gives a maximum likelihood decoding algorithm which is based only on linear processing at the receiver. We review the encoding and decoding algorithms for various codes and provide simulation results demonstrating their performance. It is shown that using multiple transmit antennas and space–time block coding provides remarkable performance at the expense of almost no extra processing.

Index Terms—Diversity, multipath channels, multiple antennas, space–time codes, wireless communication.

I. INTRODUCTION

IN MOST situations, the wireless channel suffers attenuation due to destructive addition of multipaths in the propagation media and to interference from other users. The channel statistic is significantly often Rayleigh which makes it difficult for the receiver to reliably determine the transmitted signal unless some less attenuated replica of the signal is provided to the receiver. This technique is called diversity, which can be provided using temporal, frequency, polarization, and spatial resources [3], [6], [7]–[9], [11], [16], [17]. In many situations, however, the wireless channel is neither significantly time-variant nor highly frequency selective. This forces the system engineers to consider the possibility of deploying multiple antennas at both the transmitter and receiver to achieve spatial diversity.

Only recently has transmit diversity been studied extensively as a method of combating detrimental effects in wireless fading channels because of its relative simplicity of implementation and feasibility of having multiple antennas at the base station. The first bandwidth efficient transmit diversity scheme was proposed by Wittneben [18], and it includes the delay diversity scheme of Seshadri and Winters [10] as a special

case. Later Foschini introduced a multilayered space–time architecture [4].

More recently, space–time trellis coding has been proposed [12] which combines signal processing at the receiver with coding techniques appropriate to multiple transmit antennas and provides significant gain over [10] and [18]. Specific space–time trellis codes designed for two–four transmit antennas perform extremely well in slow fading environments (typical of indoor transmission) and come within 2–3 dB of the outage capacity computed by Telatar [15] and independently by Foschini and Gans [5]. The bandwidth efficiency is about three–four times that of current systems. The space–time codes presented in [12] provide the best possible tradeoff between constellation size, data rate, diversity advantage, and trellis complexity. When the number of transmit antennas is fixed, the decoding complexity of space–time trellis coding (measured by the number of trellis states in the decoder) increases exponentially as a function of both the diversity level and the transmission rate.

In addressing the issue of decoding complexity, Alamouti discovered a remarkable scheme for transmission using two transmit antennas [1]. Space–time block coding, introduced in [13] and [14], generalizes the transmission scheme discovered by Alamouti to an arbitrary number of transmit antennas and is able to achieve the full diversity promised by the transmit and receive antennas. These codes retain the property of having a very simple maximum likelihood decoding algorithm based only on linear processing at the receiver [13], [14]. For real signal constellations (such as PAM), they provide the maximum possible transmission rate allowed by the theory of space–time coding [12]. For complex constellations, space–time block codes can be constructed for any number of transmit antennas, and again these codes have remarkably simple decoding algorithms based only on linear processing at the receiver. They provide full spatial diversity and half of the maximum possible transmission rate allowed by the theory of space–time coding. For complex constellations and for the specific cases of three and four transmit antennas, these diversity schemes were improved to provide 3/4 of the maximum possible transmission rate [13], [14].

The purpose of this paper is to evaluate the performance of the space–time block codes constructed in [13] and [14] and to provide the details of the encoding and decoding procedures. We begin by considering encoding and decoding algorithms for some of these codes. We then provide simulation results confirming that with space–time block coding and

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Space-time Coding and Its Applications in Efficient and Jamming-resistant Wireless Communications Leonard E. Lightfoot,2010 **Handbook of Optical Wireless Communication** Xizheng Ke,2024-08-02 The book focuses on optical wireless communication systems It summarises the author s work on optical wireless communication during the implementation of relevant scientific research plans The main contents include the research status and progress of optical wireless communication including the author s own work in this field and the research progress of domestic and foreign scholars in related fields The key technologies key components modulation and coding methods influencing factors of coherent optical communication underwater optical communication visible light communication and orbital angular momentum involved in wireless optical communication are analysed and their research progress and development trends are presented It is particularly suitable for readers interested in the field of wireless optical communications This book can benefit researchers engineers and graduate students in the field of telecommunications Suitable for engineering and technical personnel involved in optical communications university teachers postgraduate students and advanced undergraduates *Wireless Internet Of Things: Principles And Practice* Amoakoh Gyasi-agyei,2020-04-22 This textbook is clearly a valuable resource for engineering students or anyone who wants to learn about wireless communication since it provides the technical fundamentals of the key theories and methods used for IoT communication If you are interested in learning about the technical details of IoT and wireless communication then this very well written book loaded with the fundamentals for understanding this rapidly growing system of the future is well worth reading IEEE Electrical Insulation MagazineThis textbook metamorphosed from notes that the author has been using to teach at four universities in Australia and New Zealand The book treats the physical principles and design of wireless Internet of Things IoT systems from engineering perspective IoT enables communication between people between people and things and between things The book highlights the wide scope of sensors used in IoT including RFIDs smart mobile phones home consumer devices autonomous cars utility meters car park meters robots satellites radars and wireless positioning systems Three features render the book practically accessible First each chapter is organised in sections each of which ends with a set of authentic review questions to motivate reflection This is complemented by numerous worked examples in each section Third the book introduces two popular industry software packages for hands on practice MATLAB and CelPlanner With the growing popularity of softwarisation and cloudification possessing expertise in these packages makes one useful to the industry Parts of this book are taught in undergraduate curriculum while the rest is taught in graduate courses Both traditional and modern topics including C RAN network slicing NFV NB IoT and 5G use cases in IoT are covered Instructor s resources are provided for free to instructors who adopt the book as textbook for a unit course subject paper Please send your request to sales wspc com *Modulation and Coding Techniques in Wireless Communications* Evgenii Krouk,Sergei Semenov,2011-02-21 The

high level of technical detail included in standards specifications can make it difficult to find the correlation between the standard specifications and the theoretical results This book aims to cover both of these elements to give accessible information and support to readers It explains the current and future trends on communication theory and shows how these developments are implemented in contemporary wireless communication standards Examining modulation coding and multiple access techniques the book is divided into two major sections to cover these functions The two stage approach first treats the basics of modulation and coding theory before highlighting how these concepts are defined and implemented in modern wireless communication systems Part 1 is devoted to the presentation of main L1 procedures and methods including modulation coding channel equalization and multiple access techniques In Part 2 the uses of these procedures and methods in the wide range of wireless communication standards including WLAN WiMax WCDMA HSPA LTE and cdma2000 are considered An essential study of the implementation of modulation and coding techniques in modern standards of wireless communication Bridges the gap between the modulation coding theory and the wireless communications standards material Divided into two parts to systematically tackle the topic the first part develops techniques which are then applied and tailored to real world systems in the second part Covers special aspects of coding theory and how these can be effectively applied to improve the performance of wireless communications systems   **Signal Processing for Mobile Communications Handbook** Mohamed Ibnkahla,2004-08-16 In recent years a wealth of research has emerged addressing various aspects of mobile communications signal processing New applications and services are continually arising and future mobile communications offer new opportunities and exciting challenges for signal processing The Signal Processing for Mobile Communications Handbook provi   *Designing Space-time Codes Using Orthogonal Designs* Girish Ganesan,2002   **Optical Wireless Communication** Xizheng Ke,Ke Dong,2022-07-01 The book gives a detailed description of optical wireless communication OWC including optical laser communication visible light communication ultraviolet communication underwater optical communication and future communication technologies To achieve an integration between theory and practice the book avoids tedious mathematical deductions and includes theoretical materials as exercises Most of the exercises are originated from published journal articles These exercises will aid the readers in understanding the basic concept and methods and evaluating their knowledge acquisition in the field of OWC The book is structured into Ten chapters that covers main aspects of OWC Optical wireless communication system Coherent optical communication Modulation demodulation and coding Atmospheric channel channel estimation and channel equalization White LED communication Underwater laser communication Ultraviolet communication Acquisition aiming and tracking technology Partially coherent optical transmission Optical communication in the future The book is a suitable reference for undergraduate or postgraduate students majored in communication engineering electronic information engineering or computer science as well as the engineers and technicians in related fields   Wireless Communications over MIMO

<u>Channels</u> Volker Kuhn,2006-07-11 Wireless Communications over MIMO Channels Applications to CDMA and Multiple Antenna Systems covers both state of the art channel coding concepts and CDMA and multiple antenna systems rarely found in other books on the subject Furthermore an information theoretical analysis of CDMA and SDMA systems illuminate ultimate limits and demonstrates the high potential of these concepts Besides spatial multiplexing the use of multiple transmit antennas in order to increase the link reliability by diversity concepts space time coding is described Another focus is the application of error control coding in mobile radio communications Accompanying appendices include basic derivations tables of frequently used channel models chain rules for entropy and information data processing theorem basics of linear algebra Householder reflection and Givens rotation and the LLL algorithm for lattice reduction *Wireless Communications Systems Design* Haesik Kim,2015-08-06 em style mso bidi font style normal Wireless Communications Systems Design provides the basic knowledge and methodology for wireless communications design The book mainly focuses on a broadband wireless communication system based on OFDM OFDMA system because it is widely used in the modern wireless communication system It is divided into three parts wireless communication theory part I wireless communication block design part II and wireless communication block integration part III Written by an expert with various experience in system design standards research and development *Conference Proceedings* ,2004 *Design of Scalable ARQ Retransmission Using MIMO Differential Space-time Block Codes* Tahmineh Kazemi,2007 **1998 IEEE International Symposium on Information Theory** ,1998 The special theme of ISIT 98 is the 50th anniversary of the founding of the field of information theory in Claude Shannon s 1948 paper A Mathematical Theory of Communication Topics in these papers on the conference include nomadic computing and CDMA in war and peace **Proceedings** ,2005 **2002 MILCOM** ,2002 <u>Conference Record</u> ,2001 **2003 IEEE 58th Vehicular Technology Conference** IEEE Vehicular Technology Society Staff,2004 **Proceedings of the ... IEEE Workshop on Signal Processing Advances in Wireless Communications** ,2003 *Journal of Zhejiang University* ,2007 <u>Chinese Journal of Electronics</u> ,2008 <u>Low Complexity, High Speed VLSI Architectures for Error Correction Decoders</u> Yanni Chen,2003

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