

# Orthogonal Space-Time Block Coding for V2V LOS Links with Ground Reflections

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**Abstract**—This work presents a capacity analysis of space-time block codes (STBC) for vehicle-to-vehicle (V2V) communication in modified line-of-sight (LOS) scenarios. The aim is to assess how performance of the V2V LOS channel is influenced by ground reflections. STBCs of various coding rates are evaluated using antenna elements distributed over the surface of two contiguous vehicles. A multi-ray tracing tool is used to model the multiple constructive/destructive interference patterns of the transmitted/received signals by all pairs of Tx/Rx antenna links. The results show that STBCs are capable of counteracting the fades produced by the destructive self-interference components across a range of inter-vehicle distances. Notably, the effectiveness of STBCs in deep fades is shown to outperform schemes with exclusive receive diversity. Higher-order STBCs with rate losses are also evaluated, showing interesting gains even for low coding rate performance, particularly, when accompanied by a multiple antenna receiver. Overall, these results can shed light on how to exploit transmit diversity in slow fading vehicular channels.

**Index Terms**—LOS, MIMO, STBC, Two-ray model, V2V.

## I. INTRODUCTION

Vehicle-to-vehicle (V2V) communication is a promising yet challenging aspect of vehicular networks and Intelligent Transportation Systems (ITS) [1]. V2V communication performance is crucial for several safety-critical vehicular applications, e.g., platooning [2], which rely on vehicles networking capabilities to improve transportation efficiency and road safety.

Multiple-input and multiple-output (MIMO) antenna systems are one of the prospective upgrades to be implemented

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in future connected vehicles [3] (including platoons), aiming at improving channel capacity and reliability with minimum spectrum efficiency losses. MIMO theory and its applications is a well-known subject in wireless communication [4], offering vast practical and theoretical knowledge with proven success in the vehicular realm.

Space-time block codes (STBC) are a classical approach to achieve transmit diversity in MIMO systems. STBCs started with the pioneering work of Alamouti in [5] who proposed an effective and low-complex pre-coding/decoding scheme over space-time dimensions. The work paved the way for several other coding techniques achieving diversity at the transmitter side. Notably, achieving results equivalent to a maximum-ratio combining (MRC) receiver [6]. While the advantages of STBCs in conventional stochastic fading channels remains well understood, its potential to counteract deterministic fading due to ground reflections has not been fully exploited for vehicular applications with time-invariant channels.

In this work, we investigate the performance of STBCs in V2V MIMO LOS links scenarios with steady traffic (see e.g. [7], [8] for further motivations), or scenarios with reduced stochastic scattering, i.e., characterized by a time-invariant LOS channel, but also highly influenced by (deterministic) ground signal reflections. This is unlike the more typical approach to counteract stochastic fading in scenarios with scattering prevalence (see e.g. [9]). The deterministic analysis is built upon our prior work in [10] where we established the V2V channel model to account for self-interference patterns that appear when using multiple antennas with ground reflections. Specifically, STBCs of various coding rates are evaluated across a range of inter-vehicle distances. Interestingly, the capacity results reveal gains that outperform schemes of exclusive receive diversity. These results suggest STBCs can be used as a valid option to mitigate deterministic fades in V2V MIMO LOS channels showing slow or time-invariant statistics.

## II. RELATED WORK & MOTIVATION

MIMO technology lies at the core of improved connectivity towards the next generation of wireless communication systems [11]. STBCs are a simple but rather powerful MIMO solutions with a still unexplored performance in vehicular

# Space Time Block Coding Mit

**Arturo Cuomo**



## **Space Time Block Coding Mit:**

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 *Space-time Coding and Its Applications in Efficient and Jamming-resistant Wireless Communications* Leonard E. Lightfoot, 2010

**Modulation and Coding Techniques in Wireless Communications** Evgenii Krouk, Sergei Semenov, 2011-01-19 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 *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 Magazine This 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

### **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 provides *Designing Space-time Codes Using Orthogonal Designs* Girish Ganesan, 2002 *Wireless Communications over MIMO Channels* 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

**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 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 **Journal of Zhejiang University** ,2007 **Conference Record** ,2001 **2002 MILCOM** ,2002 *Proceedings of the ... IEEE Workshop on Signal Processing Advances in Wireless Communications* ,2003 **2003 IEEE 58th Vehicular Technology Conference** IEEE Vehicular Technology Society Staff,2004 *Chinese Journal of Electronics* ,2008 **Low Complexity, High Speed VLSI Architectures for Error Correction Decoders** Yanni Chen,2003

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