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Mohinder Jankiraman

# space-time codes and **MIMO** systems

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# Space-Time Codes and MIMO Systems

Mohinder Jankiraman



E200600887



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**Library of Congress Cataloging-in-Publication Data**

Jankiraman, Mohinder.

Space-time codes and MIMO systems / Mohinder Jankiraman.

p. cm. — (Artech House universal personal communications series)

Includes bibliographical references and index.

ISBN 1-58053-865-7 (alk. paper)

1. Space time codes. 2. MIMO systems. 3. Wireless communication systems. 4. Antenna arrays. I. Title. II. Series.

TK5103.4877.J36 2004

621.382—dc22

2004050668

**British Library Cataloguing in Publication Data**

Jankiraman, Mohinder

Space-time codes and MIMO systems. — (Artech House universal personal communications library)

1. Coding theory 2. Wireless communication systems

I. Title

621.3'822

ISBN 1-58053-865-7

**Cover design by Yekaterina Ratner**

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685 Canton Street

Norwood, MA 02062

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International Standard Book Number: 1-58053-865-7

Library of Congress Catalog Card Number: 2004050668

10 9 8 7 6 5 4 3 2 1

# **Space-Time Codes and MIMO Systems**

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*Dedicated to my late father  
Kuppuswamy Janakiraman  
and to my mother  
Gnanambal Janakiraman*

*Their extraordinary sacrifices made it possible for me to come this far*

# Preface

This book is intended to introduce space-time coding and multiantenna systems. The endeavor is to impart a working knowledge of the subject not just for students and researchers but for the entire wireless community.

The birth of multiantenna systems is the direct result of the long-standing struggle to achieve data rates without compromising the quality of the reception. Indeed this has been the case since the inception of wireless communications. A binding constraint in the evolution of high data rate systems is the stringent limitation imposed on the available spectrum. This, in turn, has given rise to more efficient signaling techniques. Recent study has shown that multiple antennas yield substantial increases in channel capacity. Toward this end, multiple-input multiple-output (MIMO) systems have been constructed comprising multiple antenna arrays at both ends of the wireless link. Space-time coding, as the name suggests, involves coding across space and time and is aimed at approaching the capacity limits of MIMO channels. Today space-time coding and MIMO systems are widely regarded as the most likely candidates for futuristic high data rate systems and are already being designed by many companies for the high data rate market.

This book is intended for postgraduate students, practicing engineers, and researchers. It is assumed that the reader is familiar with basic digital communications, linear algebra, and probability theory.

In view of the fact that space-time coding theory has become such a widely discussed and researched topic in recent times, it is not possible to cover all aspects in any detail. Therefore, an effort has been made to impart to the reader a “flavor” of the subject just enough to whet his/her appetite, prompting further detailed study of areas of particular interest. Toward this end, the style of writing has been kept as simple as possible and technical clichés and jargon have been kept to a minimum. All effort has been made to explain the basics in a cogent and conversational manner.

The reader is also introduced to a new technique of interfacing CDMA to OFDM systems called “Hybrid OFDM/CDMA.” This approach is different from the popular OFDM/CDMA systems proposed by Fazel et al [1], wherein an MC-CDMA system transmits each bit using OFDM modulation. In the approach suggested by the author a CDMA system is directly interfaced to an OFDM system. This approach yields a CDMA system capable of handling high throughputs, bandwidth permitting, along with the added bonus of user separation based on CDMA codes. It is, to the best of the author’s knowledge and belief, the first time such a concept has been discussed anywhere and had formed part of the author’s Ph.D. thesis [2]. This concept has been recently proved in the field by NTT DoCoMo

of Japan, wherein the company tested such a system for outdoor use using a bandwidth of 100 MHz to achieve a throughput of 100 Mbps [3] in the downlink. Further details are not known at the time of going to press. The company plans to introduce this, as part of its 4G effort, by 2010.

The teaching effort in this book is aided by a set of accompanying software. This software has been divided into a set of two broad classes—narrowband and wideband. The narrowband software is distributed on the basis of chapters and directly pertains to topics discussed in those chapters. The wideband software is orthogonal frequency division multiplexing (OFDM) based and is included as part of Chapters 7, 8, and 9. The entire coding has been kept simple and sometimes very unprofessional to enable readers to clearly understand the various steps involved in the implementation of the program. If the reader finds this annoying, the error is mine and is deeply regretted! The entire coding has been implemented at baseband and the radio frequency (RF) aspects of coding have been avoided for similar reasons. Because the software is basically intended as a “skeleton,” the user is encouraged to modify it in any manner or means by adding to its RF capability and so on to suit one’s convenience. This is an excellent method to learn the subject. The software presupposes a sound understanding of MATLAB® and SIMULINK® and has been tested on MATLAB® Version 6.0 (with Signal Processing and Communication Toolboxes) and above with the SIMULINK® option with DSP and Communication Blocksets. It is important to note that in a technology of this nature the best way to assimilate the subject is by programming. Coding an operation forces the user to look at all aspects of the subject. This is similar to learning mathematics through solving problems.

A consistent set of notations has been used throughout the book and excessive mathematics has been avoided. Emphasis is placed on imparting to the reader a physical understanding of the subject so that the reader has a clear grasp of the processes involved.

There will be errors even though every effort has been made to detect and eliminate them. Any inconvenience to the readers as a result is deeply regretted.

## References

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# Acknowledgments

It is not possible to generate a work of this nature without invaluable help from many other participants, since no man is an island. It is not possible to list all of them but I gratefully acknowledge those who helped in the preparation of this book. This invaluable help came in two principal areas—the preparation of the text and the coding of the software. I gratefully thank Dr. John Terry of Nokia Research Center, Dallas, Texas, and Michelle Johnson of Pearson Education for permission to reproduce certain figures in this book. I also thank Professor Ted Rappaport of the University of Texas at Austin for his help with obtaining permission for figures from his book, as well as Emily McGee of Pearson Education. My thanks are also due to Dr. Branka Vucetic of the University of Sydney, Australia, for her patience with my many questions. I also thank Duncan James of John Wiley & Sons for permission to use certain figures in this book. Special thanks are also due to Steve Thanos of Pentek for permission to reproduce Figure 1.3. I thank Dr. Donald Shaver of Texas Instruments for permission to reproduce Figure 1.2, and Dr. Peter Rysavy of Rysavy Research for permission to reproduce Figure 1.4(b). Thanks are also due to Dr. Richard van Nee of Airgonetworks, Netherlands, for permission to use certain figures from his book. My thanks are due to Professor Arogyaswami Paulraj of Stanford University and Ted Gerney of Cambridge University Press for permission to use certain figures in this book. Finally, I thank Jacqueline Hansson and Claudio Stanziola of IEEE for their kind permission to reproduce certain papers and figures in this book. You all have been very patient with my requests!

In addition, I thank Devendra Prasad and Albena Mihovska of the University of Aalborg, Denmark, for their invaluable help with this book. Without their help, this effort would not have been possible.

The software developed for this book has many participants. Thanks are due to Beza Negash Getu of the University of Aalborg, Denmark, for his help with the software in Chapters 2 and 4. We had many hours of fruitful discussion. Thanks are also due to Dr. Persifoni Kyritsi of Stanford University for her help with the software in Chapter 6. Persa and I thoroughly analyzed the MIMO channel. I also thank Kamil Anis of the Department of Radio Engineering, Faculty of Electrical Engineering, at Czech Technical University in Prague for his invaluable help with the space-time trellis coding in Chapter 5. In fact many of his programming ideas are incorporated in the software of Chapter 5. I also thank Dr. John Terry and Juha Heiskala of Nokia Research Center in Dallas for helping me understand the coding aspects of OFDM-based MIMO. They were very understanding and patient. I also thank Martin Clark of Mathworks, the makers of MATLAB®, for his help

in obtaining permission from Mathworks to use his software in Chapter 8. Finally, I thank Efrayim Metin of Versatel Nederland B.V., Amsterdam, Netherlands, for his invaluable help with my many software problems. I am truly grateful.

A work of this nature also requires salubrious surroundings. I thank my sister Uma and her husband, Dr. M. J. Rangaraj of Monroe, Louisiana, for inviting me to their wonderful home on the Louisiana bayou. There is no better spot than sitting on the banks of the bayou on a sunny day and mulling over technical problems surrounded by cormorants, butterflies, and noisy frogs. I solved many of my knotty problems in Louisiana. I also thank my children, Pavan and Pallavi, for their patience and encouragement.

Finally, I wish to acknowledge the advice and comments from my anonymous reviewers. I thank them all. Thanks are also due to Christine Barnaby Daniele, Tiina Ruonamaa, Julie Lancashire, Judi Stone, and Jill Stoodley of Artech House for their patience with my many corrections and repeated “final versions.” I acknowledge their superb support and efficient handling of this publication project.

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