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Applications of Algebra to Communications, Control, and Signal Processing

Springer

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ISSN 2191-5768 ISSN 2191-5776 (electronic)
ISBN 978-1-4614-3862-5 ISBN 978-1-4614-3863-2 (eBook)
DOI 10.1007/978-1-4614-3863-2
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2012935583

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

This book is dedicated to my wife, Susan Ann Boston.

Preface

Over the years, engineers and computer scientists have increasingly begun to use mathematical tools. Currently, it is standard for students in these fields to learn some complex analysis, probability, and statistics. There has, however, been a quietly growing introduction of tools from abstract algebra. Traditionally these have been used mostly in coding theory and cryptography, but there are emerging new areas of application for abstract algebra. For example, the first Applied Algebra Days conference, co-organized by the author and Shamgar Gurevich, took place in October, attracting speakers from Berkeley, Chicago, MIT, and other eminent institutions. That same month, the SIAM Activity Group in Algebraic Geometry held its first biannual conference. Both conferences covered very new approaches to applying algebra and both attracted researchers from mathematics, electrical engineering, and computer science.

This book is based on a 2004 course given by the author for graduate students from the Departments of Mathematics, Electrical Engineering, and Computer Science at the University of Wisconsin, but also incorporates a few more recent developments. It gathers into themes some of the main tools that are used today in applications and explains how they are used. This book should appeal to mathematicians wishing to see where what they know gets applied and to engineers and computer scientists wanting to learn more useful, modern tools.

Madison, WI

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January 2012

Acknowledgements

Back in 1992, while visiting the Isaac Newton Institute in Cambridge, UK, which had just opened and where the library had very few books, I read the coding theory book by Van der Geer and Van Lint and suggested to my then student, Judy Walker, that she look into the subject. There began a journey into applications of algebra that was made easier by many helpful colleagues at the University of Illinois at Urbana-Champaign, most notably Dick Blahut and Ralf Koetter, but also Alex Vardy, Pierre Moulin, and Yi Ma. Since moving to the University of Wisconsin in 2002, several others have helped me in this quest, including Rob Nowak, Yu Hen Hu, Chuck Dyer, Steve Wright, and Bob Barmish. Outside of these institutions, other colleagues including Rob Calderbank, Gary McGuire, Judy Walker, Michael Gastpar, and Joachim Rosenthal, all of whom have worked on introducing deep algebraic tools into electrical engineering, have always been of the utmost help. I thank you all.

Contents

Acronyms

fpf	Fixed-point-free
LFSR	Linear feedback shift register
PSK	Phase-shift keying
SNR	Signal-to-noise ratio
STBC	Space-time block code
STTC	Space-time trellis code