Radar Systems Analysis and Design Using MATLAB

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CHAPMAN & HALL/CRC
Boca Raton London New York Washington, D.C.

Library of Congress Cataloging-in-Publication Data

Mahafza, Bassem R.
Radar systems & analysis and design using Matlab
p. cm.
Includes bibliographical references and index.
ISBN 1-58488-182-8 (alk. paper)
1. Radar. 2. System analysis—Data processing. 3. MATLAB. I. Title.

TK6575 .M27 2000
521.38484—dc21 00-026914
CIP

International Standard Book Number 1-58488-182-8
Library of Congress Card Number 00-026914
Printed in the United States of America 4 5 6 7 8 9 0
Printed on acid-free paper

Preface

Numerous books have been written on Radar Systems and Radar Applications. A limited set of these books provides companion software. There is need for a comprehensive reference book that can provide the reader with hands-on-like experience. The ideal radar book, in my opinion, should serve as a conclusive, detailed, and useful reference for working engineers as well as a textbook for students learning radar systems analysis and design. This book must assume few prerequisites and must stand on its own as a complete presentation of the subject. Examples and exercise problems must be included. User friendly software that demonstrates the theory needs to be included. This software should be reconfigurable to allow different users to vary the inputs in order to better analyze their relevant and unique requirements, and enhance understanding of the subject.

Radar Systems Analysis and Design Using MATLAB® concentrates on radar fundamentals, principles, and rigorous mathematical derivations. It also provides the user with a comprehensive set of MATLAB[1] 5.0 software that can be used for radar analysis and/or radar system design. All programs will accept user inputs or execute using the default set of parameters. This book will serve as a valuable reference to students and radar engineers in analyzing and understanding the many issues associated with radar systems analysis and design. It is written at the graduate level. Each chapter provides all the necessary mathematical and analytical coverage required for good understanding of radar theory. Additionally, dedicated MATLAB functions/programs have been developed for each chapter to further enhance the understanding of the theory, and provide a source for establishing radar system design requirements. This book includes over 1190 equations and over 230 illustrations and plots. There are over 200 examples and end-of-chapter problems. A solutions manual will be made available to professors using the book as a text. The philosophy behind *Radar Systems Analysis and Design Using MATLAB* is that radar systems should not be complicated to understand nor difficult to analyze and design.

All MATLAB programs and functions provided in this book can be downloaded from the CRC Press Web site (*www.crcpress.com*). For this purpose, create the following directory in your C-drive: *C:\RSA*. Copy all programs into this directory. The path tree should be as in Fig. F.1 in Appendix F. Users can execute a certain function/program GUI by typing: *file_name_driver*, where

1. All MATLAB functions and programs provided in this book were developed using MATLAB 5.0 - R11 with the Signal Processing Toolbox, on a PC with Windows 98 operating system.

file names are as indicated in Appendix F. The MATLAB functions and programs developed in this book include all forms of the radar equation: pulse compression, stretch processing, matched filter, probability of detection calculations with all Swerling models, High Range Resolution (HRR), stepped frequency waveform analysis, ghk tracking filter, Kalman filter, phased array antennas, and many more.

The first part of Chapter 1 describes the most common terms used in radar systems, such as range, range resolution, Doppler frequency, and coherency. The second part of this chapter develops the radar range equation in many of its forms. This presentation includes the low PRF, high PRF, search, bistatic radar, and radar equation with jamming. Radar losses are briefly addressed in this chapter. Chapter 2 discusses the Radar Cross Section (RCS). RCS dependency on aspect angle, frequency, and polarization are discussed. Target scattering matrix is developed. RCS formulas for many simple objects are presented. Complex object RCS is discussed, and target fluctuation models are introduced. Continuous wave radars and pulsed radars are discussed in Chapter 3. The CW radar equation is derived in this chapter. Resolving range and Doppler ambiguities is also discussed in detail.

Chapter 4 is intended to provide an overview of the radar probability of detection calculations and related topics. Detection of fluctuating targets including Swerling I, II, III, and IV models is presented and analyzed. Coherent and non-coherent integrations are also introduced. Cumulative probability of detecting analysis is in this chapter. Chapter 5 reviews radar waveforms, including CW, pulsed, and LFM. High Range Resolution (HRR) waveforms and stepped frequency waveforms are also analyzed.

The concept of the matched filter, and the radar ambiguity function constitute the topics of Chapter 6. Detailed derivations of many major results are presented in this chapter, including the coherent pulse train ambiguity function. Pulse compression is in Chapter 7. Analog and digital pulse compressions are also discussed in detail. This includes fast convolution and stretch processors. Binary phase codes and frequency codes are discussed.

Chapter 8 presents the phenomenology of radar wave propagation. Topics like multipath, refraction, diffraction, divergence, and atmospheric attenuation are included. Chapter 9 contains the concepts of clutter and Moving Target Indicator (MTI). Surface and volume clutter are defined and the relevant radar equations are derived. Delay line cancelers implementation to mitigate the effects of clutter is analyzed.

Chapter 10 has a brief discussion of radar antennas. The discussion includes linear and planar phased arrays. Conventional beamforming is in this chapter. Chapter 11 discusses target tracking radar systems. The first part of this chapter covers the subject of single target tracking. Topics such as sequential lobing, conical scan, monopulse, and range tracking are discussed in detail. The

second part of this chapter introduces multiple target tracking techniques. Fixed gain tracking filters such as the $\alpha\beta$ and the $\alpha\beta\gamma$ filters are presented in detail. The concept of the Kalman filter is introduced. Special cases of the Kalman filter are analyzed in depth.

Synthetic Aperture Radar (SAR) is the subject of Chapter 12. The topics of this chapter include: SAR signal processing, SAR design considerations, and the SAR radar equation. Arrays operated in sequential mode are discussed in this chapter. Chapter 13 presents an overview of signal processing. Finally, six appendices present discussion on the following: noise figure, decibel arithmetic, tables of the Fourier transform and Z-transform pairs, common probability density functions, and the MATLAB program and function name list.

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Huntsville, Alabama
January, 2000

Acknowledgment

I would like to acknowledge the following for help, encouragement, and support during the preparation of this book. First, I thank God for giving me the endurance and perseverance to complete this work. I could not have completed this work without the continuous support of my wife and four sons. The support and encouragement of all my family members and friends are appreciated. Special thanks to Dr. Andrew Ventre, Dr. Michael Dorsett, Mr. Edward Shamsi, and Mr. Skip Tornquist for reviewing and correcting different parts of the manuscript. Finally, I would like to thank Mr. Frank J. Collazo, the management, and the family of professionals at COLSA Corporation for their support.

To my sons:

Zachary,

Joseph,

Jacob, and

Jordan

To:

My Wife,

My Mother,

and the memory of my Father

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