

TN82 F334

Adaptive Antennas and Phased Arrays for Radar and Communications

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Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the U.S. Library of Congress.

British Library Cataloguing in Publication Data A catalogue record for this book is available from the British Library.

ISBN 13: 978-1-59693-273-9

Cover design by Igor Valdman

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This work was sponsored in part under Air Force Contract FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the author and are not necessarily endorsed by the United States Air Force.

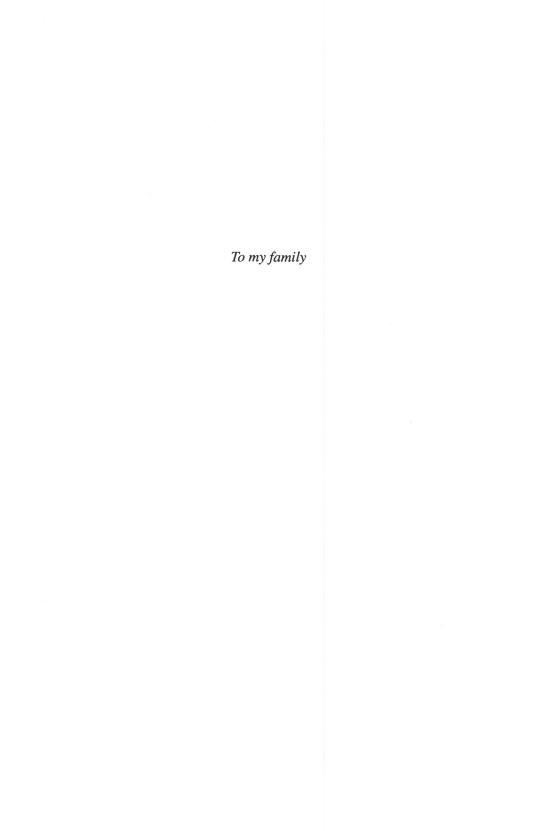
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Adaptive Antennas and Phased Arrays for Radar and Communications

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Preface

Adaptive antennas and phased arrays, with rapidly scanned beams or multiple beams, are commonly suggested for radar and communications systems in ground-based, airborne, and spaceborne applications that must function in the presence of jamming and other sources of interference. This monograph is written primarily for practicing antenna engineers and graduate students in electrical engineering, and describes research on adaptive antennas and phased arrays that I have performed with my colleagues at MIT Lincoln Laboratory. A portion of the material in this book has been published previously only in Lincoln Laboratory reports, and some of the material has been published in the peer-reviewed literature. Most of the information in this book is not available in other books. No prior knowledge of adaptive antennas or phased arrays is needed to understand the content of this book, although some background in signal processing, electromagnetic theory, antennas, radar, and communications will be helpful to the reader.

The book begins with a discussion of the fundamentals of adaptive antennas pertaining to radar and communications systems, with an emphasis on consumption of adaptive array degrees of freedom from the jammer's viewpoint. Displaced phase center antenna array mutual coupling effects in the problem of adaptive suppression of radar clutter is discussed in Chapter 2. Next, in Chapters 3 through 5 a theoretical foundation for a focused near-field technique that can be used to quantify the far-field adaptive nulling performance of a large aperture adaptive phased array system is described. Simulations of focused near-field and focused far-field nulling performance for adaptive arrays are presented for arrays of isotropic elements in Chapter 3, for arrays including mutual coupling effects in Chapters 4 and 5, and for arrays with multiple phase centers in Chapter 5. Experimental testing of the focused near-field adaptive nulling technique for phased arrays is described in

Chapter 6. An experimental high-resolution multiple-beam adaptive-nulling antenna system is described in Chapter 7.

Chapters 8 through 16 then concentrate on phased array antenna development for a variety of array elements. Chapter 8 provides an introduction to phased array antenna theory. In Chapter 9, finite and infinite array analyses and measurements for periodic phased arrays of monopole elements are presented. Chapter 10 describes the focused near-field polarization characteristics of monopole phased arrays as related to adaptive array testing in the near field. Next, in Chapter 11 a test bed phased array that implements the displaced phase center antenna technique, as related to the analysis presented in Chapter 2, is described along with the planar near field testing technique that is used to assess adaptive clutter cancellation performance. The planar near field scanning method for measuring low-sidelobe radiation patterns of phased arrays is described in Chapter 12. Experimental arrays of horizontally polarized loop-fed slotted cylinder antennas (Chapter 13), dual-polarized dipole arrays (Chapter 14), and ultrawideband dipole arrays (Chapter 15) are described. In Chapter 16, rectangular waveguide arrays are analyzed by the method of moments.

Some of the data contained in this monograph are due to the efforts of a number of colleagues at MIT Lincoln Laboratory, most notably H.M. Aumann and F.G. Willwerth. Technical discussions with A.J. Simmons, L.J. Ricardi, E.J. Kelly, G.N. Tsandoulas, R.W. Miller, D.H. Temme, S.C. Pohlig, and J.R. Johnson are sincerely appreciated. The software support of L. Niro, D.S. Besse, S.E. French, and D.L. Washington is also greatly appreciated. For the material presented in Chapter 7, B.M. Potts and W.C. Cummings developed the 127-beam distributed MBA concept, A.R. Dion developed the MBA lenses, J.C. Lee developed the feed horns, D.C. Weikle developed the RF nulling weight network, and R.J. Burns organized the multiple beam antenna measurements Technical discussions with Professor B.A. Munk of The Ohio State University ElectroScience Laboratory were very helpful to the infinite array analysis presented in Chapter 9. Assistance in preparation of the manuscript is due to Ms. Loretta Wesley. Madeline Riley coordinated the preparation of the graphics.

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1

Adaptive Antennas and Degrees of Freedom

1.1 INTRODUCTION

The subject of adaptive antenna systems has been explored extensively since the 1950s [1-13]. The primary function of any adaptive nulling receive antenna system for radar [14, 15] or communications [3-5] applications is to minimize (null) the received power from one or more interference sources located in the antenna field of view as depicted in Figure 1.1. In the case of a radar application, the adaptive antenna system may need to suppress radar clutter [15] as well as to cancel interference from intentional jamming or unintentional interference. Additionally, the adaptive nulling system must have constraints that allow the system to detect radar targets or to receive signals from desired communications users with an adequate signal-to-noise ratio (SNR). The ability of the adaptive nulling antenna system to perform these functions is governed by a number of factors, some of which include the number of adaptive array elements (or nulling channels), antenna aperture diameter, nulling bandwidth, and number, strength, and locations of interfering sources.

An adaptive antenna can be, for example, a microwave or millimeter-wave phased array antenna [16-20] consisting of multiple antenna elements in which the main beam is electronically steered over the field of view. Alternately, the adaptive antenna can be a multiple beam antenna (MBA) [21, 22] consisting of multiple horn antennas feeding a parabolic reflector antenna system or lens antenna system [23].

A typical adaptive nulling antenna system block diagram is shown in Figure 1.2. The adaptive antenna generally has degrees of freedom in the