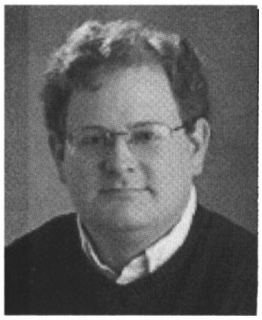

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Introduction to Direction-of-Arrival Estimation, by Zhizhang Chen, Gopal Gokeda, and Yiqiang Yu, Norwood, MA, Artech House, 2010, 193 pages, ISBN 978-1-59693-089-6.

The subject of signal detection and location is of great importance to many commercial and military systems. Numerous books and papers on the topic have been published during the past several decades. This book attempts to provide an introduction to the fundamental mathematical theory of the signal-processing algorithms used for direction-of-arrival (DOA) estimation. In particular, about half of the text (Chapters 5 and 6) is devoted to the algorithm known as ESPRIT, which is an acronym for "Estimation of Signal Parameters via Rotational Invariance Techniques."

Introduction to Direction-of-Arrival Estimation contains seven chapters. Chapter 1, a concise, high-level introduction to smart antennas, focuses on the basic hardware block diagram of a smart-antenna receiver. The authors summarize the processes performed by the adaptive antenna processor, including model-order estimation, DOA estimation, and spatial filtering, the subjects of this book. The ten pages of Chapter 2 very briefly discuss antennas and arrays. Linear and planar arrays are used to explain all DOA algorithms in the following chapters. The authors derive a matrix equation that describes the signals received by the elements of a linear array, which reappears frequently in the following chapters.

Chapter 3 reviews basic DOA-estimation algorithms. The assumptions, or data model, used throughout the book are that the signals of interest are narrowband, located in an isotropic and linear transmission medium, and in the far field of the receiving array. The linear array serves as a vehicle to highlight the objective of DOA: extraction of the spatial frequencies from the signals received by the array. Placement of the array elements periodically within a half-wavelength prevents a grating-lobe-induced ambiguity in DOA determination. The authors then discuss the properties of centro-symmetric arrays, which are required by many DOA algorithms. The concept of covariance matrix and noise are introduced next. The simplest approach to DOA involves steering the array beam in the direction of the signal of interest, and correlating the peak in the beamformer output. The authors use an example of two closely spaced signals to illustrate the limited spatial resolution of this approach. They then describe Capon's beamformer, which weights the array-element responses so as to place nulls in the directions of the undesired signals. Subsequent sections introduce ever-more-powerful DOA algorithms, ending with subspace techniques, including MUSIC (multiple signal classification), minimum norm, and ESPRIT.

Chapter 4 begins by stating that coherent signals, such as those received in a multipath environment, will cause many algorithms to fail unless the data covariance matrix is processed before DOA estimation. Preprocessing schemes, such as forward-backward averaging and spatial smoothing, are described. The second topic of the chapter is model-order estimation, which involves estimating the number of signals incident on the receiving array. All DOA estimation algorithms require knowledge of this number. Estimators discussed include the minimum descriptive length and the Akaike Information Theoretic criteria.

The remaining ninety pages of the book, Chapters 5 and 6, are devoted to ESPRIT. Chapter 5 explains the principles of ESPRIT in linear algebraic form, starting with standard ESPRIT, based on complex-valued mathematics, with linear arrays. The discussion then moves to the real-valued version, called Unitary ESPRIT. Because arrays with large numbers of elements are often used, computational requirements can become intense. Consequently, the authors discuss beam-space algorithms, which transform the data into the beam space, which is significantly lower in dimension. The final section of the chapter covers Unitary ESPRIT in DFT beam space.

Chapter 6, "Analysis of ESPRIT-Based DOA Estimation Algorithms," attempts to provide insight into the performance of ESPRIT by using simple DOA scenarios. The capability of the algorithm to resolve the DOA of signals is evaluated using small arrays, most of which are linear and have less than a dozen elements. DOA estimation error is evaluated as a function of parameters including signal-to-noise ratio, number of signals, number elements, uniformity of signal power, and angle of separation. I found these examples somewhat repetitive, and the authors' conclusions about them almost too obvious. Section 6.3 was intended to be a "performance comparison between the standard ESPRIT and the unitary ESPRIT...." However, it seems that some sort of accident happened during the publishing/proofing process, because none of the plots seems to be comparing unitary and standard ESPRIT. The word "standard" does not appear in the legend in any of the dozen or so graphs in the section. The acronyms LS (Least Squares) and TLS (Total Least Squares) do appear in every plot, but they have nothing to do with unitary and standard. Moreover, the contents of the figures often do not agree with the corresponding discussion on the page. For example, the text referring to Figure 6.63 says the x axis represents the number of elements, but the label and numbers on the axis are clearly signal-to-noise ratio. In the next section, the plot in Figure 6.64 seems to be unrelated to the discussion on page 169 that references it. I am surprised these major errors were not caught by any of the authors. I have written two books for the same publisher, and the authors should have had at least two opportunities to catch

the errors in this part of the book before the book was printed. It seems that this important chapter was written quickly and given significantly less attention than the previous chapters.

Chapter 7 contains just two pages. The first page summarizes the discussion in the book, and the second touches on more advanced topics.

Introduction to Direction of Arrival Estimation is a clearly written tutorial on the mathematics of the basic DOA algorithms. My overall impression of this book leads me to infer that the authors have a solid understanding of said mathematics, but little practical experience using them in real systems. I confirmed my impression when I read the "About the Authors" biographies at the back of the book. Not one of the biographies mentions any publications or experience in the field of DOA algorithm development and implementation. In summary, this book will be of interest to students and hardware and software engineers just starting to work in the field of signal location and identification. Those in search of more practical implementation tips and/or more advanced DOA topics will have to look elsewhere.

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Recent Books

The following is a list of recently published books that have been received by the Associate Editor since the last issue of the *Magazine* was published. Reviewers are sought for these books, so readers are encouraged to let the Associate Editor know if they are interested in reviewing a particular book.

Computational Electromagnetics for RF and Microwave Engineering, Second Edition, David F. Davidson (Cambridge, 2011)

Electromagnetic Scattering and Material Characterization, Abbas Omar (Artech House, 2011)