JPL Space Science and Technology Series

Joseph H. Yuen, Series Editor

Synthetic Aperture Radar Polarimetry

Jakob Van Zyl and Yunjin Kim

Jet Propulsion Laboratory
California Institute of Technology

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Note from the Series Editor

The Jet Propulsion Laboratory (JPL) Space Science and Technology Series broadens the range of the ongoing JPL Deep Space Communications and Navigation Series to include disciplines other than communications and navigation in which JPL has made important contributions. The books are authored by scientists and engineers with many years of experience in their respective fields, and lay a foundation for innovation by communicating state-of-the-art knowledge in key technologies. The series also captures fundamental principles and practices developed during decades of space exploration at JPL, and celebrates the successes achieved. These books will serve to guide a new generation of scientists and engineers.

We would like to thank the Office of the Chief Scientist and Chief Technologist for their encouragement and support. In particular, we would like to acknowledge the support of Thomas A. Prince, former JPL Chief Scientist; Erik K. Antonsson, former JPL Chief Technologist; Daniel J. McCleese, JPL Chief Scientist; and Paul E. Dimotakis, JPL Chief Technologist.

Joseph H. Yuen, Editor-in-Chief
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Foreword

I am very pleased to commend the Jet Propulsion Laboratory (JPL) Space Science and Technology Series, and to congratulate and thank the authors for contributing their time to these publications. It is always difficult for busy scientists and engineers, who face the constant pressures of launch dates and deadlines, to find the time to tell others clearly and in detail how they solved important and difficult problems, so I applaud the authors of this series for the time and care they devoted to documenting their contributions to the adventure of space exploration.

JPL has been NASA's primary center for robotic planetary and deep-space exploration since the Laboratory launched the nation's first satellite, Explorer 1, in 1958. In the 50 years since this first success, JPL has sent spacecraft to all the planets except Pluto, studied our own planet in wavelengths from radar to visible, and observed the universe from radio to cosmic ray frequencies. Current plans call for even more exciting missions over the next decades in all these planetary and astronomical studies, and these future missions must be enabled by advanced technology that will be reported in this series. The JPL Deep Space Communications and Navigation book series captured the fundamentals and accomplishments of these two related disciplines, and we hope that this new series will expand the scope of those earlier publications to include other space science, engineering, and technology fields in which JPL has made important contributions.

I look forward to seeing many important achievements captured in these books.

CHARLES ELACHI, Director
Jet Propulsion Laboratory
California Institute of Technology

Preface

The fundamentals of radar polarimetry were built on a long history of research in optics. However, the fact that the radar is an active instrument, allowing one the extra flexibility to change the polarization of the transmitted wave in addition to optimizing the receiving antenna polarization, opened new doors to more powerful analysis of scattering from different types of terrain.

This book describes the application of polarimetric synthetic aperture radar to earth remote sensing based on our research at the Jet Propulsion Laboratory (JPL). Many important contributions to the field of radar polarimetry have been made long before we joined the field. Giants in the field include Kennaugh, Sinclair, Huynen, Boerner and many others. Our contribution is to put their work to practice in the field of synthetic aperture radar (SAR), but we owe thanks to these pioneers for pointing the way.

There is a vast amount of literature available on radar polarimetry. Here we did not try to reproduce or summarize all of these. Instead we concentrated our effort on compiling a subset of the knowledge into a reference that we hope would prove useful to both the newcomer and the expert in radar polarimetry. We provide a concise description of the mathematical fundamentals illustrated with many examples using SAR data. Our treatment of the subject is focused on remote sensing of the earth, and the examples are chosen to illustrate this application.

We start with the basics of synthetic aperture radar to provide the basis for understanding how polarimetric SAR images are formed. We follow this introduction with the fundamentals of radar polarimetry. We next discuss some of the more advanced polarimetric concepts that allow one to infer more information about the terrain being imaged. In order to analyze data quantitatively, however, the signals must be calibrated carefully. We included a

chapter summarizing the basic calibration algorithms. We conclude our discussion with an example of applying polarimetric analysis to scattering from rough surfaces with the aim to infer soil moisture from the radar signals.
Much still remains to be discovered about the best ways to extract all the information out of polarimetric SAR data. We hope that by preparing this work we have helped to accelerate this process by providing the next generation of researchers with some of the tools to make those discoveries.

Jakob van Zyl and Yunjin Kim
Pasadena, California
December 2010

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We would like to express our appreciation to Joseph H. Yuen for his encouragement of us in generating this book and to Roger Carlson, Judi Dedmon, and John Kovacic for their editing and layout. We also thank all of our colleagues who contributed by providing us with the excellent synthetic aperture radar data. We have been privileged to work with them over the years. Likewise, through the years, we have collaborated with many researchers all over the globe. We thank them for their help in shaping our insight into the analysis of polarimetric SAR data.

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Authors

Jakob van Zyl received his Hons. B. Engineering (*Cum Laude*) in electronics engineering from the University of Stellenbosch, South Africa in 1979. Dr. Van Zyl received his MS and Ph D in electrical engineering from the California Institute of Technology (Pasadena, California) in 1983 and 1986, respectively. He has been with the Jet Propulsion Laboratory in Pasadena, California since 1986. At JPL he contributed to the design and development of many synthetic aperture radar (SAR) systems, including SIR-C, SRTM, AIRSAR, TOPSAR, and GeoSAR. In 1997 he received the Fred Nathanson Memorial Radar Award for advancement of radar polarimetry, radar interferometry, and synthetic aperture radar from the Aerospace and Electronics Society of the IEEE. In 2010 he received the Distinguished Achievement Award from the Geoscience and Remote Sensing Society of the IEEE for his contributions to polarimatric SAR remote sensing. He is currently the Director for Astronomy and Physics at the Jet Propulsion Laboratory.

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