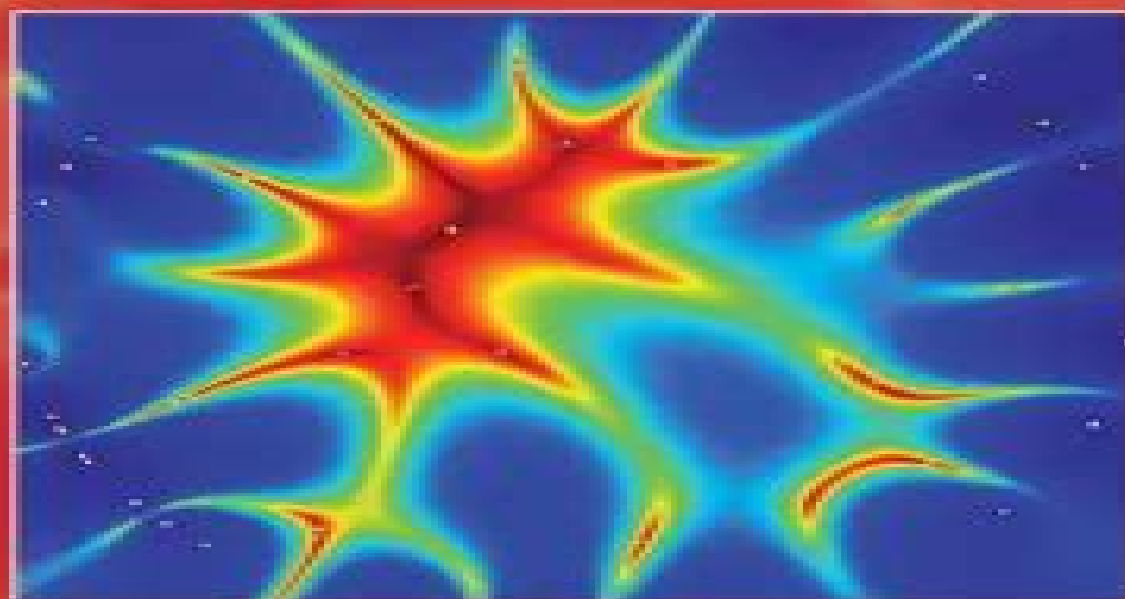


# MATHEMATICAL FOUNDATIONS OF IMAGING, TOMOGRAPHY AND WAVEFIELD INVERSION



Anthony J. Devaney

# Mathematical Foundations Of Imaging Tomography And Wavefield Inversion

**Vasudevan Lakshminarayanan, María  
L. Calvo, Tatiana Alieva**



## **Mathematical Foundations Of Imaging Tomography And Wavefield Inversion:**

**Mathematical Foundations of Imaging, Tomography and Wavefield Inversion** Anthony J. Devaney, 2012-06-21

Inverse problems are of interest and importance across many branches of physics mathematics engineering and medical imaging In this text the foundations of imaging and wavefield inversion are presented in a clear and systematic way The necessary theory is gradually developed throughout the book progressing from simple wave equation based models to vector wave models By combining theory with numerous MATLAB based examples the author promotes a complete understanding of the material and establishes a basis for real world applications Key topics of discussion include the derivation of solutions to the inhomogeneous and homogeneous Helmholtz equations using Green function techniques the propagation and scattering of waves in homogeneous and inhomogeneous backgrounds and the concept of field time reversal Bridging the gap between mathematics and physics this multidisciplinary book will appeal to graduate students and researchers alike Additional resources including MATLAB codes and solutions are available online at [www.cambridge.org/9780521119740](http://www.cambridge.org/9780521119740)

*Mathematical Foundations of Imaging, Tomography and Wavefield Inversion* Anthony J. Devaney, 2012 Inverse problems are of interest and importance across many branches of physics mathematics engineering and medical imaging In this text the foundations of imaging and wavefield inversion are presented in a clear and systematic way The necessary theory is gradually developed throughout the book progressing from simple wave equation based models to vector wave models By combining theory with numerous MATLAB based examples the author promotes a complete understanding of the material and establishes a basis for real world applications Key topics of discussion include the derivation of solutions to the inhomogeneous and homogeneous Helmholtz equations using Green function techniques the propagation and scattering of waves in homogeneous and inhomogeneous backgrounds and the concept of field time reversal Bridging the gap between mathematics and physics this multidisciplinary book will appeal to graduate students and researchers alike Additional resources including MATLAB codes and solutions are available online at [www.cambridge.org/9780521119740](http://www.cambridge.org/9780521119740)

**Handbook of Mathematical Models and Algorithms in Computer Vision and Imaging** Ke Chen, Carola-Bibiane

Schönlieb, Xue-Cheng Tai, Laurent Younes, 2023-02-24 This handbook gathers together the state of the art on mathematical models and algorithms for imaging and vision Its emphasis lies on rigorous mathematical methods which represent the optimal solutions to a class of imaging and vision problems and on effective algorithms which are necessary for the methods to be translated to practical use in various applications Viewing discrete images as data sampled from functional surfaces enables the use of advanced tools from calculus functions and calculus of variations and nonlinear optimization and provides the basis of high resolution imaging through geometry and variational models Besides optimization naturally connects traditional model driven approaches to the emerging data driven approaches of machine and deep learning No other framework can provide comparable accuracy and precision to imaging and vision Written by leading researchers in imaging

and vision the chapters in this handbook all start with gentle introductions which make this work accessible to graduate students For newcomers to the field the book provides a comprehensive and fast track introduction to the content to save time and get on with tackling new and emerging challenges For researchers exposure to the state of the art of research works leads to an overall view of the entire field so as to guide new research directions and avoid pitfalls in moving the field forward and looking into the next decades of imaging and information services This work can greatly benefit graduate students researchers and practitioners in imaging and vision applied mathematicians medical imagers engineers and computer scientists

*Industrial Tomography* Mi Wang, 2022-05-07 *Industrial Tomography Systems and Applications* Second Edition thoroughly explores the important techniques of industrial tomography also discusses image reconstruction systems and applications This book presents complex processes including the way three dimensional imaging is used to create multiple cross sections and how computer software helps monitor flows filtering mixing drying processes and chemical reactions inside vessels and pipelines This book is suitable for materials scientists and engineers and applied physicists working in the photonics and optoelectronics industry or in the applications industries Provides a comprehensive discussion on the different formats of tomography including advances in visualization and data fusion Includes an excellent overview of image reconstruction using a wide range of applications Presents a comprehensive discussion of tomography systems and their applications in a wide variety of industrial processes

*Bone Quantitative Ultrasound* Pascal Laugier, Quentin Grimal, 2022-05-05 Many significant achievements in new ultrasound technologies to measure bone and models to elucidate the interaction and the propagation of ultrasonic waves in complex bone structures have been reported over the past ten years Impaired bone remodeling affects not only the trabecular compartment but also the cortical one Despite the crucial contribution of the cortical structure to the whole bone mechanical competence cortical bone was understudied for a long time A paradigm shift occurred around 2010 with a special focus placed on the importance of cortical bone This has sparked a great deal of interest in new ultrasound techniques to assess cortical bone While our book *Bone Quantitative Ultrasound* published in 2011 emphasized techniques to measure trabecular bone this new book is devoted for a large part to the technologies introduced recently to measure cortical bone These include resonant ultrasound spectroscopy guided waves scattering and pulse echo and tomography imaging techniques Instrumentation signal processing techniques and models used are detailed Importantly the data accumulated in recent years such as anisotropic stiffness elastic engineering moduli compression and shear wave speeds of cortical bones from various skeletal sites are presented comprehensively A few chapters deal with the recent developments achieved in quantitative ultrasound of trabecular bone These include i scattering based approaches and their application to measure skeletal sites such as the spine and proximal femur and ii approaches exploiting the poro elastic nature of bone While bone fragility and osteoporosis are still the main motivation for developing bone QUS this Book also includes chapters reporting ultrasound techniques developed for other applications of high interest

such as 3 D imaging of the spine assessment of implant stability and transcranial brain imaging This book together with the book Bone Quantitative Ultrasound published in 2011 will provide a comprehensive overview of the methods and principles used in bone quantitative ultrasound and will be a benchmark for all novice or experienced researchers in the field The book will offer recent experimental results and theoretical concepts developed so far and would be intended for researchers graduate or undergraduate students engineers and clinicians who are involved in the field The book should be considered as a complement to the first book published in 2011 rather than a second edition in the sense that basic notions already presented in the first book are not repeated

Computational Methods for Electromagnetic Inverse Scattering Xudong Chen, 2018-03-07 A comprehensive and updated overview of the theory algorithms and applications of for electromagnetic inverse scattering problems Offers the recent and most important advances in inverse scattering grounded in fundamental theory algorithms and practical engineering applications Covers the latest most relevant inverse scattering techniques like signal subspace methods time reversal linear sampling qualitative methods compressive sensing and noniterative methods Emphasizes theory mathematical derivation and physical insights of various inverse scattering problems Written by a leading expert in the field

Fundamentals of Ultrasonic Phased Arrays Lester W. Schmerr Jr., 2014-08-13 This book describes in detail the physical and mathematical foundations of ultrasonic phased array measurements The book uses linear systems theory to develop a comprehensive model of the signals and images that can be formed with phased arrays Engineers working in the field of ultrasonic nondestructive evaluation NDE will find in this approach a wealth of information on how to design optimize and interpret ultrasonic inspections with phased arrays The fundamentals and models described in the book will also be of significant interest to other fields including the medical ultrasound and seismology communities A unique feature of this book is that it presents a unified theory of imaging with phased arrays that shows how common imaging methods such as the synthetic aperture focusing technique SAFT the total focusing method TFM and the physical optics far field inverse scattering POFFIS imaging method are all simplified versions of more fundamental and quantitative imaging approaches called imaging measurement models To enhance learning this book first describes the fundamentals of phased array systems using 2 D models so that the complex 3 D cases normally found in practice can be more easily understood In addition to giving a detailed discussion of phased array systems Fundamentals of Ultrasonic Phased Arrays also provides MATLAB functions and scripts allowing the reader to conduct simulations of ultrasonic phased array transducers and phased array systems with the latest modeling technology

**Microwave Imaging Methods and Applications** Matteo Pastorino, Andrea Randazzo, 2018-06-30 Microwave Imaging Methods and Applications provides practitioners and researchers with a complete overview of the latest and most important noninvasive and nondestructive techniques for inspecting structures and bodies by using microwaves Placing emphasis on applications the book considers many areas from medical imaging and security to industrial engineering and subsurface prospection For each application readers are presented with

the objectives of the inspection and related challenges Moreover this groundbreaking resource details computational methods that can be used to solve inverse problems related to specific applications Including clear examples or the most significant practical results this forward looking reference focuses on systems that have been recently developed Professionals gain the knowledge needed to compare imaging methods used in different applications and develop new uses of imaging apparatuses and systems

**A Data Engineering Approach to Wave Scattering Analysis with Applications in Radar, Sonar, Medical Diagnostics, Structural Flaw Detection and Intelligent Robotics** Mark Hinders, 2025-01-02

Comprehensive resource exploring how recent advancements in computational capabilities open doors to new applications in wave scattering A Data Engineering Approach to Wave Scattering Analysis applies scattering analysis to many applications including radar sonar medical diagnosis intelligent robotics and more enabling readers to implement new and better measurements with both novel instrumentation and artificial intelligence that automates the interpretation of various and multiple imaging data streams Composed of 10 chapters this book brings together separate scientific topics that share a common basis of knowledge and their unchanged mathematical techniques to ensure successful results Through periodic exercises this book reinforces the importance of revisiting derivations and reproducing established results It also delves into the individuals who shaped scientific methods and technologies exploring 81 notable names and providing insights into their professional journeys Classic results from scattering are included in each chapter and rather than simply pasting in plots from classic papers these results have largely been reproduced for a more coherent reader experience Written by an established academic in the field A Data Engineering Approach to Wave Scattering Analysis includes information on various topics Field equations covering strain as a dimensionless measure of deformation generalized Hooke's Law and elastic and acoustic waves Reflection and refraction covering reflection from a free surface and surface waves as well as the wave model of acoustic microscopy Guided waves covering torsional modes longitudinal waves and flexural waves in rods as well as data engineering for lamb wave tomography Inverse scattering covering wavelet transforms and fingerprinting as well as applications of wavelet fingerprints such as roof fall detection A Data Engineering Approach to Wave Scattering is an essential up to date reference on the subject for researchers interested in radar sonar medical imaging structural health monitoring manufacturing process control and autonomous vehicles as well as upper level undergraduates and graduate students in related programs of study

*Radar Scattering and Imaging of Rough Surfaces* Kun-Shan Chen, 2020-11-19

Radar scattering and imaging of rough surfaces is an active interdisciplinary area of research with many practical applications in fields such as mineral and resource exploration ocean and physical oceanography military and national defense planetary exploration city planning and land use environmental science and many more By focusing on the most advanced analytical and numerical modeling and describing both forward and inverse modeling Radar Scattering and Imaging of Rough Surfaces Modeling and Applications with MATLAB connects the scattering process to imaging techniques

by vivid examples through numerical and experimental demonstrations and provides computer codes and practical uses This book is unique in its simultaneous treatment of radar scattering and imaging Key Features Bridges physical modeling with simulation for resolving radar imaging problems the first comprehensive work to do so Provides excellent basic and advanced information for microwave remote sensing professionals in various fields of science and engineering Covers most advanced analytical and numerical modeling for both backscattering and bistatic scattering Includes MATLAB codes useful not only for academics but also for radar engineers and scientists to develop tools applicable in different areas of earth studies Covering both the theoretical and the practical Radar Scattering and Imaging of Rough Surfaces Modeling and Applications with MATLAB is an invaluable resource for professionals and students using remote sensing to study and explain the Earth and its processes University and research institutes electrical and radar engineers remote sensing image users application software developers students and academics alike will benefit from this book The author Kun Shan Chen is an internationally known and respected engineer and scientist and an expert in the field of electromagnetic modeling

**Transionospheric Synthetic Aperture Imaging** Mikhail Gilman,Erick Smith,Semyon Tsynkov,2017-04-13 This landmark monograph presents the most recent mathematical developments in the analysis of ionospheric distortions of SAR images and offers innovative new strategies for their mitigation As a prerequisite to addressing these topics the book also discusses the radar ambiguity theory as it applies to synthetic aperture imaging and the propagation of radio waves through the ionospheric plasma including the anisotropic and turbulent cases In addition it covers a host of related subjects such as the mathematical modeling of extended radar targets as opposed to point wise targets and the scattering of radio waves off those targets as well as the theoretical analysis of the start stop approximation which is used routinely in SAR signal processing but often without proper justification The mathematics in this volume is clean and rigorous no assumptions are hidden or ambiguously stated The resulting work is truly interdisciplinary providing both a comprehensive and thorough exposition of the field as well as an accurate account of a range of relevant physical processes and phenomena The book is intended for applied mathematicians interested in the area of radar imaging or more generally remote sensing as well as physicists and electrical electronic engineers who develop operate spaceborne SAR sensors and perform the data processing The methods in the book are also useful for researchers and practitioners working on other types of imaging Moreover the book is accessible to graduate students in applied mathematics physics engineering and related disciplines Praise for Transionospheric Synthetic Aperture Imaging I perceive that this text will mark a turning point in the field of synthetic aperture radar research and practice I believe this text will instigate a new era of more rigorous image formation relieving the research development and practitioner communities of inconsistent physical assumptions and numerical approaches Richard Albanese Senior Scientist Albanese Defense and Energy Development LLC

*Mathematical Optics* Vasudevan Lakshminarayanan,María L. Calvo,Tatiana Alieva,2018-10-08 Going beyond standard introductory texts Mathematical Optics Classical Quantum and

Computational Methods brings together many new mathematical techniques from optical science and engineering research. Profusely illustrated, the book makes the material accessible to students and newcomers to the field. Divided into six parts, the text presents state-of-the-art mathematical methods and applications in classical optics, quantum optics, and image processing. Part I describes the use of phase space concepts to characterize optical beams and the application of dynamic programming in optical waveguides. Part II explores solutions to paraxial linear and nonlinear wave equations. Part III discusses cutting-edge areas in transformation optics such as invisibility cloaks and computational plasmonics. Part IV uses Lorentz groups, dihedral group symmetry, Lie algebras, and Liouville space to analyze problems in polarization ray optics, visual optics, and quantum optics. Part V examines the role of coherence functions in modern laser physics and explains how to apply quantum memory channel models in quantum computers. Part VI introduces super-resolution imaging and differential geometric methods in image processing. As numerical symbolic computation is an important tool for solving numerous real-life problems in optical science, many chapters include Mathematica code in their appendices. The software codes and notebooks, as well as color versions of the book's figures, are available at [www.crcpress.com](http://www.crcpress.com).

**Electromagnetic Wave Propagation, Radiation, and Scattering** Akira Ishimaru, 2017-09-05. One of the most methodical treatments of electromagnetic wave propagation, radiation, and scattering, including new applications and ideas. Presented in two parts, this book takes an analytical approach on the subject and emphasizes new ideas and applications used today. Part one covers fundamentals of electromagnetic wave propagation, radiation, and scattering. It provides ample end-of-chapter problems and offers a 90-page solution manual to help readers check and comprehend their work. The second part of the book explores up-to-date applications of electromagnetic waves, including radiometry, geophysical remote sensing and imaging, and biomedical and signal processing applications. Written by a world-renowned authority in the field of electromagnetic research, this new edition of *Electromagnetic Wave Propagation, Radiation, and Scattering: From Fundamentals to Applications* presents detailed applications with useful appendices, including mathematical formulas, Airy function, Abel's equation, Hilbert transform, and Riemann surfaces. The book also features newly revised material that focuses on the following topics: Statistical wave theories, which have been extensively applied to topics such as geophysical remote sensing, bioelectromagnetics, biooptics, and bio-ultrasound imaging; Integration of several distinct yet related disciplines such as statistical wave theories, communications, signal processing, and time reversal imaging; New phenomena of multiple scattering such as coherent scattering and memory effects; Multiphysics applications that combine theories for different physical phenomena such as seismic coda waves, stochastic wave theory, heat diffusion, and temperature rise in biological and other media; Metamaterials and solitons in optical fibers, nonlinear phenomena, and porous media. Primarily a textbook for graduate courses in electrical engineering, *Electromagnetic Wave Propagation, Radiation, and Scattering* is also ideal for graduate students in bioengineering, geophysics, ocean engineering, and geophysical remote sensing. The book is also a useful reference for engineers and scientists working

in fields such as geophysical remote sensing bio medical engineering in optics and ultrasound and new materials and integration with signal processing

**The World of Applied Electromagnetics** Akhlesh Lakhtakia, Cynthia M. Furse, 2017-08-08 This book commemorates four decades of research by Professor Magdy F Iskander Life Fellow IEEE on materials and devices for the radiation propagation scattering and applications of electromagnetic waves chiefly in the MHz THz frequency range as well on electromagnetics education This synopsis of applied electromagnetics stemming from the life and times of just one person is meant to inspire junior researchers and reinvigorate mid level researchers in the electromagnetics community The authors of this book are internationally known researchers including 14 IEEE fellows who highlight interesting research and new directions in theoretical experimental and applied electromagnetics

**Mathematical Modelling** Hemen Dutta, 2023-06-12 This volume is a collection of chapters that present several key principles and theories as well as their potential uses in the development of mathematical models in areas like waves thermodynamic electromagnetics fluid dynamics and catastrophes The techniques and methodologies used in this book on the other hand should have a long term impact and be applicable to a wide range of different topics of study and research Each chapter should also help readers in gaining a better knowledge of the underlying and connected concepts The companion volume Contemporary Mathematics Volume 787 is devoted to theory and application

**Functional Analysis** Joseph Muscat, 2014-07-23 This textbook is an introduction to functional analysis suited to final year undergraduates or beginning graduates Its various applications of Hilbert spaces including least squares approximation inverse problems and Tikhonov regularization should appeal not only to mathematicians interested in applications but also to researchers in related fields Functional Analysis adopts a self contained approach to Banach spaces and operator theory that covers the main topics based upon the classical sequence and function spaces and their operators It assumes only a minimum of knowledge in elementary linear algebra and real analysis the latter is redone in the light of metric spaces It contains more than a thousand worked examples and exercises which make up the main body of the book

*Inverse Scattering Theory and Transmission Eigenvalues* Fioralba Cakoni, David Colton, Housseem Haddar, 2022-12-07 Inverse scattering theory is a major theme in applied mathematics with applications to such diverse areas as medical imaging geophysical exploration and nondestructive testing The inverse scattering problem is both nonlinear and ill posed thus presenting challenges in the development of efficient inversion algorithms A further complication is that anisotropic materials cannot be uniquely determined from given scattering data In the first edition of Inverse Scattering Theory and Transmission Eigenvalues the authors discussed methods for determining the support of inhomogeneous media from measured far field data and the role of transmission eigenvalue problems in the mathematical development of these methods In this second edition three new chapters describe recent developments in inverse scattering theory In particular the authors explore the use of modified background media in the nondestructive testing of materials and methods for determining the modified transmission eigenvalues that arise in such

applications from measured far field data They also examine nonscattering wave numbers a subset of transmission eigenvalues using techniques taken from the theory of free boundary value problems for elliptic partial differential equations and discuss the dualism of scattering poles and transmission eigenvalues that has led to new methods for the numerical computation of scattering poles This book will be of interest to research mathematicians and engineers and physicists working on problems in target identification It will also be useful to advanced graduate students in many areas of applied mathematics

**Inverse Acoustic and Electromagnetic Scattering Theory** David Colton,Rainer Kress,2019-11-06 The inverse scattering problem is central to many areas of science and technology such as radar sonar medical imaging geophysical exploration and nondestructive testing This book is devoted to the mathematical and numerical analysis of the inverse scattering problem for acoustic and electromagnetic waves In this fourth edition a number of significant additions have been made including a new chapter on transmission eigenvalues and a new section on the impedance boundary condition where particular attention has been made to the generalized impedance boundary condition and to nonlocal impedance boundary conditions Brief discussions on the generalized linear sampling method the method of recursive linearization anisotropic media and the use of target signatures in inverse scattering theory have also been added

*Signal and Image Processing for Remote Sensing* C.H. Chen,2024-06-11 Advances in signal and image processing for remote sensing have been tremendous in recent years The progress has been particularly significant with the use of deep learning based techniques to solve remote sensing problems These advancements are the focus of this third edition of *Signal and Image Processing for Remote Sensing* It emphasizes the use of machine learning approaches for the extraction of remote sensing information Other topics include change detection in remote sensing and compressed sensing With 19 new chapters written by world leaders in the field this book provides an authoritative examination and offers a unique point of view on signal and image processing

**Features** Includes all new content and does not replace the previous edition Covers machine learning approaches in both signal and image processing for remote sensing Studies deep learning methods for remote sensing information extraction that is found in other books Explains SAR microwave seismic GPR and hyperspectral sensors and all sensors considered Discusses improved pattern classification approaches and compressed sensing approaches Provides ample examples of each aspect of both signal and image processing This book is intended for university academics researchers postgraduate students industry and government professionals who use remote sensing and its applications

**Electromagnetic and Optical Pulse Propagation** Kurt E. Oughstun,2019-07-17 In two volumes this book presents a detailed systematic treatment of electromagnetics with application to the propagation of transient electromagnetic fields including ultrawideband signals and ultrashort pulses in dispersive absorptive media This expanded updated and reorganized new edition presents a rigorous development of both time and frequency domain electromagnetics from classical theory to current topics in applied research on temporally pulsed wave fields in dielectric conducting and semiconducting materials

With meaningful exercises throughout it is suitable as a graduate textbook in electromagnetic wave theory and will be of use to researchers as a resource on electromagnetic radiation and wave propagation theory with applications to radar imaging communications and safety issues Volume 1 develops the fundamental Maxwell Lorentz theory of microscopic electromagnetics and its relationship to macroscopic electromagnetics in complex media with particular emphasis given to temporally dispersive materials supplemented with several appendices on mathematical methods The second edition includes new material on conjugate electromagnetic fields time reversal invariance the four potential and Lorentz invariance anisotropic and spatially dispersive media double negative metamaterials and generalized Fresnel reflection and refraction coefficients for complex media The relationship between both the mathematical and physical interpretation of classical electromagnetic field theory with the special theory of relativity is emphasized throughout the volume Volume 2 covers temporal pulse dynamics in dispersive attenuative media with asymptotic analysis at the forefront

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