

# DIAGNOSTIC ULTRASOUND

Imaging and Blood  
Flow Measurements

SECOND EDITION



K. Kirk Shung



CRC Press  
Taylor & Francis Group

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Imaging and Blood  
Flow Measurements

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SECOND EDITION



# *Dedication*

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*This book is dedicated to my wife,  
Linda, and three children,  
Albert, Simon, and May, and their spouses,  
Rini, Jenny, and Chris.*



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# *Preface*

The field of medical imaging is advancing at a rapid pace. Imaging modalities such as x-ray radiography, x-ray computed tomography (CT), ultrasound, nuclear imaging, magnetic resonance imaging (MRI), and optical imaging have been used in biology and medicine to visualize anatomical structures as large as the lung and liver and as small as molecules. Ultrasound is considered the most cost-effective among them all. It is used routinely in hospitals and clinics for diagnosing a variety of diseases and is considered the tool of choice in obstetrics and cardiology because it is safe and capable of providing images in real time. New applications in pre-clinical or small animal imaging and cellular imaging are being explored.

Although there have been many clinical books published for ultrasound, very few technical books are available. Over the past 35 years, this has been a major problem for the author in teaching a graduate course in ultrasonic imaging at the Department of Bioengineering, Pennsylvania State University, and the Department of Biomedical Engineering, University of Southern California. It is for this purpose that this book was written. The book is intended to be a textbook for a senior-level or first-year graduate-level course in ultrasonic imaging in a biomedical engineering, electrical engineering, medical physics, or radiological sciences curriculum. An attempt has been made to minimize mathematical derivation and to place more emphasis on physical concepts. In this edition, several chapters, including the chapter on transducers, were greatly expanded. Chapter 1 gives an overview of the field of ultrasonic imaging and its role in diagnostic medicine relative to other imaging modalities. Chapters 2 and 3 describe the fundamental physics involved and a crucial device in ultrasound, ultrasonic transducers, respectively. Conventional imaging approaches and Doppler measurements are given in Chapters 4 and 5. More recent developments, including contrast imaging and 4D imaging, are described in Chapters 6 to 9. In Chapter 10, current status and standards on ultrasound bioeffects are reviewed. Chapter 11 discusses methods that have been used to measure ultrasonic properties of tissues. This chapter is optional and may be eliminated at the discretion of the instructor. At the end of each chapter a list of relevant references and further reading materials is given.



Material contained in the book should be more than sufficient for a one-semester graduate- or senior-level course.

The book should also be of interest to radiologists with some technical background and practicing engineers and physicists working in the imaging industry.

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# About the Author

**K. Kirk Shung** obtained a Ph.D. in electrical engineering from University of Washington, Seattle, in 1975. He is a Dean's Professor in Biomedical Engineering, an endowed position, at University of Southern California and has been the director of NIH Resource Center on Medical Ultrasonic Transducer Technology since 1997.

Dr. Shung is a life fellow of IEEE and a fellow of the Acoustical Society of America and American Institute of Ultrasound in Medicine. He is a founding fellow of American Institute of Medical and Biological Engineering. Dr. Shung received the IEEE Engineering in Medicine and Biology Society Early Career Award in 1985 and was the coauthor of a paper that received the best paper award for *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control* (UFFC) in 2000. He was selected as the distinguished lecturer for the IEEE UFFC society for 2002-2003. In 2010 and 2011, he received the Holmes Pioneer Award in Basic Science from American Institute of Ultrasound in Medicine and the academic career achievement award from the IEEE Engineering in Medicine and Biology Society.

Dr. Shung has published more than 500 papers and book chapters. He is the author of a textbook *Principles of Medical Imaging* published by Academic Press in 1992 and a textbook *Diagnostic Ultrasound: Imaging and Blood Flow Measurements* published by CRC press in 2005. He co-edited a book *Ultrasonic Scattering by Biological Tissues* published by CRC Press in 1993. Dr. Shung is currently serving as an associate editor of *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, *IEEE Transactions on Biomedical and Engineering*, and *Medical Physics*. Dr. Shung's research interest is in ultrasonic transducers, high frequency ultrasonic imaging, ultrasound microbeam, and ultrasonic scattering in tissues.



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