Preface

This is the third book I have written on ultrasonic waves and their applications to the nondestructive evaluation (NDE) of materials and structures. The first book (Schmerr, L.W., Fundamentals of Ultrasonic Nondestructive Evaluation—A Modeling Approach, Plenum Press, New York, N.Y., 1998) covered the behavior of elastic waves (primarily bulk waves) in terms of their generation, propagation, scattering, and reception in an NDE system and described the use of models in applications such as flaw classification and sizing. The second book, with Prof. Sung-Jin Song, (Schmerr, L.W. and S-J. Song, Ultrasonic Nondestructive Evaluation Systems—Models and Measurements, Springer, New York, N.Y., 2007) was a more complete systems-level effort to use a combination of models and measurements to describe in detail all the elements that go into forming the signals that we measure in an ultrasonic NDE test. In both of those books the primary focus was on ultrasonic measurements with single element piezoelectric transducers. The present book arose out of a realization that ultrasonic phased array systems, which are now starting to see significant NDE applications in industry, have many unique characteristics and issues that have not been adequately described except in journal papers and conference proceedings.

In organizing the structure of this book and writing it I have had three purposes in mind. First, while I did not want to generate a textbook I did want to introduce some of the basic physics behind ultrasonic phased arrays in a simple context so that the important aspects these systems could be readily accessible to students, engineers, and technical workers. Thus, many of the initial discussions of phased array topics such as beam steering, delay laws, apodization, etc. are in terms of 1-D array elements radiating waves in two dimensions. Second, I wanted to follow the basic philosophy of the previous books by showing how all the components of an ultrasonic phased array system can either be measured or modeled, using a combination of reciprocity relations, linear systems theory, and wave propagation and scattering theory. This approach allows one to develop *ultrasonic measurement models* for NDE phased array systems in the same fashion as done previously for inspections with single element transducers. These measurement models demonstrate explicitly how signals are produced in ultrasonic phased array systems and in particular how the responses of flaws are contained in those signals, so that those flaw responses can be extracted and used for quantitative flaw detection, sizing and characterization purposes. Third, because of the importance of imaging applications with phased arrays, I wanted to introduce a new, rational approach to how images are produced and what they mean. Currently, phased array images are often formed with ad-hoc *delay-and-sum methods* such as the synthetic aperture focusing technique (SAFT) and the total focusing method (TFM). I have re-examined the image formation process to understand why those delay-and-sum methods often work so well and to place them in a more fundamental context based on the physics of the measurement process. Specifically, I show that one can start with ultrasonic measurement models and, with relatively few assumptions, based on a model of the waves that contribute to an image, formally invert those measurement models to form flaw images that are explicit functions of the surface geometry and reflectivity of the flaw. These images are related to the measured signals and the wave propagation processes and electro-acoustical components present in a phased array experiment in a form called an *imaging measurement model*. Imaging measurement models are developed that are generalizations of both SAFT and TFM. These models describe the images produced in physical terms and define those aspects of the imaging process that SAFT and TFM ignore. For small flaws it is shown that the imaging measurement models are also generalizations of the physical optics far field inverse scattering (POFFIS) method originally developed by Bojarski and later modified by Bleistein. Thus, the imaging measurement models described here provide for the first time a unified framework for understanding some of the most commonly used NDE phased array imaging methods.

To help make some of the phased array models described in the book more accessible to the reader, MATLAB® functions and scripts[1] are also provided. Most of these MATLAB® resources describe simple 2-D and 3-D scalar problems that one can use to conduct a variety of parametric studies. The intent here was not to produce a comprehensive set of phased array software but to provide some software tools for examining and understanding phased arrays. Listings of the MATLAB® functions and scripts can be found in Appendix C and the m-files are also available by sending an e-mail with subject titled "Phased Array Codes" to the author at lschmerr@cnde.iastate.edu.

Finally, I would like to thank my longtime colleague and friend, Alex Sedov, for his contributions and for reading and helping to edit the entire book. I also want to acknowledge the research efforts of Dr. Ruiju Huang and Brady Engle which have helped to make this work possible.

[1] MATLAB® is a registered trademark of the The MathWorks, Inc.

Springer
http://www.springer.com/978-3-319-07271-5

Fundamentals of Ultrasonic Phased Arrays
Schmerr Jr, L.W.
2015, XII, 377 p. 266 illus., 38 illus. in color., Hardcover
ISBN: 978-3-319-07271-5