Nonlinear Acoustics
Robert T. Beyer
Acoustical Society of America, Melville, NY, (1997), 452 pp., hardcover, ASA members 45.00 USD, Non-members 70.00 USD, ISBN 1-56396-724-3

and

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Mark F. Hamilton and David T. Blackstock, Editors
Acoustical Society of America, Melville, NY, (2008), 455 pp., hardbound, ASA members 45.00 USD, Non-members 70.00 USD, ISBN 0-9744067-5-9

These two books on nonlinear acoustics span a period of almost 25 years when referring to the dates of their original publication, 1974 and 1997, respectively. The older one, written entirely by Robert T. Beyer (1920–2008), former Professor of Physics at Brown University. The newer one, edited by M. F. Hamilton and D. T. Blackstock, both from the University of Texas in Austin, are a compilation of 15 chapters, each written by different authors.

Beyer's book is printed on US letter-size paper format, thus, giving the false impression of a text book resulting from lecturing. Owing to this paper size, almost all diagrams and pictures are of a remarkable large size which makes them easy to study and understand. Derivation of equations uses multiple steps, to not just show the initial step and the final result. In other words, it is a book on nonlinear acoustics for reading.

The book splits into 12 chapters, each ending with an exhaustive reference list:

1. "Introduction" — using the "normal" wave equation as a starting point (being a linear approximation for low Mach numbers) and explaining some historical aspects of non-linear effects, such as vortex sound, shock waves, radiation pressure, streaming and cavitation.
2. "Principles of Linear Acoustics" — discusses vibrations supposed to be linear acoustics, but in fact being approximations of more general non-linear phenomena (e.g. linear vibrations of a string at "small" displacements, i.e. "small" compared with the string's length, or radiation from a piston, not only into far-field and at low frequencies).
3. "Some Sources of Nonlinear Oscillations" — reflects on a simple pendulum, non-linear springs (like most "real springs"), membranes (with "infinite" small thickness) and plates (with finite thickness) as two-dimensional examples — further an excursus to the non-linearity of the human ear (keyword: "Tartini" tones).
4. "Nonlinear Propagation in Fluids" — is the largest chapter of the book covering more than 60 pages, discussing the effect of compressibility and the famous B/A ratio term (parameter of nonlinearity). The chapter explains the development of theories on the propagation of sounds in fluids, including Blackstock's bridging function, the editor/author of the second book in this review (so forming a "bridge" in a double sense).
5. "Shock Waves" — became relevant with more and more powerful technical sources of sound/noise, such as explosions, artillery projectiles, supersonic aircraft and rockets. The physics of these effects involves some thermodynamics, depending on the medium of propagation (gazes or liquids).
6. "Aeroacoustics" — starts with an account on Lighthill's theory and discusses the basic aeroacoustic sources, such as monopole, dipole and quadrupole, closing with vortex sound ("Karman" street) as a special kind of dipole radiation.
7. "Radiation Pressure" — describes effects by beamforming of acoustical energy, in special at boundaries between liquids or between a liquid and air (known as "acoustic fountain").
8. "Streaming" — discusses bulk flow inside a fluid induced by non-linear acoustic effects when waves travel through it. For example, the motion of particles at standing waves in Kundt's tube is due to streaming.
9. "Cavitation" — presents basic phenomena using bubble theory, deriving thresholds for cavitation theoretically. Non-linearity originates here from the description of the dynamics of bubbles, both for growth and collapse. Noise is caused by collapse and by oscillation of the bubbles.
10. "Nonlinear Interaction of Sound Waves" — are an extension of the preceding chapter "Nonlinear Propagation in Fluids," this time focusing on interaction. Relevant theories developed over the decades – starting from Lighthill's theory – are discussed. These interactions may lead to absorption and scattering of sound by sound.
11. "Applications of Nonlinear Interactions" — discusses on 35 pages in detail the parametric array applied in ultrasonics, both for transmitting and receiving applications.
12. "Nonlinear Propagation in Solids" — is not so much looking at what engineers call "structure-borne sound" phenomena, but more pointing at an elastic arrangement of atoms or molecules in solids. In solid-state physics, the energy is supposed to be transmitted by "phonons" representing the "quantization" of the modes of vibrations

of elastic material. This chapter discusses non-linear effects found at lattices representing solids.

The appendix dates from 1997 and picks up all topics from the previous chapters and gives updated comments and a lot of newer references.

The book edited by Hamilton and Blackstock was originally published in the same year that the reprint of Beyer's book appeared. So, from the reader's point of view, it would be nice to know what the differences are and what book to recommend for whom — assuming you were interested in non-linear acoustics at all. To give you a clue right away, both are mathematically challenging; Beyer's book has more derivations which makes it easier for the reader to follow, but offers less topics and does not focus so much on practical applications. In opposite, the book edited by Hamilton/Blackstock covers more topics and presents a larger number of application cases where a non-linear approach is a “must”.

This book has 15 chapters dealing with the following topics (author/s in parentheses):

1. History of Nonlinear Acoustics: 1750's–1930's (Blackstock)
2. The Parameter B/A (Beyer)
3. Model Equations (Hamilton, Morfey)
4. Progressive Waves in Lossless and Lossy Fluids (Blackstock, Hamilton, Pierce)
5. Dispersion (Hamilton, Il'inskii, Zabolotskaya)
6. Radiation Pressure and Acoustic Levitation (Wang, Lee)
7. Acoustic Streaming (Nyborg)
8. Sound Beams (Hamilton)
9. Finite-Amplitude Waves in Solids (Norris)
10. Perturbation Methods (Ginsberg)
11. Computational Methods (Ginsberg, Hamilton)
12. Propagation in Inhomogeneous Media, Ray Theory (Morfey, Cotaras)
13. Statistical Phenomena (Gurbatov, Rudenko)
14. Parametric Layers, Four-Wave Mixing, and Wave-Front Reversal (Simpson, Marston)
15. Biomedical Applications (Carstensen, Bacon)

The chapters 1 to 9 match with similar chapters in Beyer's book. The further chapters 10 to 15 discuss on a very profound and sophisticated mathematical level, theories and propagation models to explain and predict phenomena requiring a non-linear approach. Most of the theories and propagation models proposed and explained rely on the knowledge of several material parameters forming the input data. So, it comes to the question on how to properly gain these material parameters to prove these theories and propagation models.

My final advice is as follows: If you are looking for a book to get a first insight into non-linear acoustics, go for Beyer's book. If you are working in the field of acoustics where non-linear approach is required, such as biomedics, you will find the book edited by Hamilton and Blackstock more challenging. You may keep in mind, however, that even the latter might not be up-to-date.

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