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Book Review

Jens Blauert, Ning Xiang, *Acoustics for Engineers – Troy Lectures*
Second Edition, Springer-Verlag, Berlin Heidelberg, 2009

The reviewed book is an introductory course on engineering acoustics designed for undergraduates with basic knowledge in mathematics. It is not written clearly enough but in my opinion is it a handbook for students of electrical engineering. Some parts of the material require the knowledge of the basics of electricity and magnetism. Particularly, there are chapters about electromechanical and electroacoustical analogies and electroacoustical transducers. It is not clear whether the course is intended for students who plan to specialize in acoustics or for those for whom this will be the only contact with engineering acoustics. In the second case basic information about physiology and psychology of hearing is missing. The book is divided into 15 chapters. The Authors write that each chapter represents material for two hours of lecture. The 15th chapter does not present a material for a lecture. It contains appendices: basic information about complex notation for sinusoidal signals, power and intensity, supplementary bibliography for self-study and exercises. In my opinion the exercises have various levels of difficulty and should be solved under the direction of a teacher. They are a very important part of the entire course.

Chapter 1 presents basic definitions in the field of acoustics, some specialized areas within acoustics, a very brief history of acoustics, and basic quantities used in acoustics with numerical examples. The logarithmic scales of the amplitude (levels) and frequency (intervals) are introduced. The basic terms defined in this chapter are the auditory event, sound and acoustics. Acoustics is defined as a science of sound and of accompanying auditory events. The mentioned lack of material about psychology and physiology of human hearing is particularly clear in the light of those definitions. In my opinion, also the history of acoustics is presented too briefly and inconsistently Some people who have made a significant contribution to the development of this field of knowledge have been omitted in this book, such people as e.g. Aristotle, Galileo Galilei, Marin Mersenne, Isaac Newton, Ernst Chladni, Pierre Laplace, Georg Simon Ohm, Hermann von Helmholtz, Graham Bell (I intentionally omitted researchers living in the XX-th century). Particularly, I would like to recall Ernst Chladni (1756–1827). He is known nowadays from "Chladni figures" – the pattern of node lines on the surface of vibrating plates, and a big part of his contribution into acoustics is forgotten. In his time Chladni was called "the father of acoustics". He was author of the book "Die Akustik" (Leipzig 1802) – the first modern and consistent handbook of acoustics. He introduced acoustics as a separate branch into physics. Last but not least, I would like to mention that Chladni died in Breslau (now Wroclaw in Poland), the city where the author of this review lives. In 2008 a Chladni relief was established in Wroclaw with participation of the Polish Acoustical Society.

In the next Chapter, the knowledge about vibration and sound is developed – from basic vibrating systems to advanced problems of structural acoustics and sound insulation in buildings. Some ideas are presented initially briefly and developed in further chapters. Thus it requires "jumps" – a sentence "see Chapter x.x for details" appears quite often in first chapters of the handbook. Chapter 2 deals with simple vibrating systems – a "parallel" mechanical oscillator as a mechanical system and the Helmholtz resonator as an acoustical one. Both are systems of one-degree-of freedom. More complicated systems are not considered in the book (except some exercises). This distinguishes the reviewed book from other handbooks in acoustics, where the vibration of mutli- (particularly two-) degree-of-freedom systems as well as further ones (strings, rods, beams, membranes and plates) are usually presented. I have two critical remarks to Chapter 2. The first one concerns the definition of a resonance. In Fig. 2.5, two curves are shown: displacement vs. frequency and velocity vs. frequency for the acting force independent on frequency. Then, two resonances can be distinguished: the displacement resonance and velocity one. The frequency of the displacement resonance depends on the natural (characteristic) frequency ω_0 and the damping coefficient δ. For $Q \leq 1/\sqrt{2}$, the displacement resonance does not appear. This knowledge is important e.g. for the consideration of the frequency response of the pressure condenser microphones (see Chapter 6.5). The frequency of the velocity resonance is always equal to ω and does not depend on damping. It is important for the construction of dynamic pressure microphones or for electrostatic pressure-gradient microphones. Then, we can distinguish rather displacement and velocity resonances than the resonance and characteristic frequencies (see page 22). I am also surprised at the use of the term "particle velocity" for the velocity of the simple mechanical oscillator (see e.g. caption of Fig. 2.6). The term "particle velocity" is used for acoustic vibrations and radiations and it can be used interchangeably with the term "acoustic velocity"(see Chapter 7). For vibration of mechanical systems the simple term "velocity" should be used.

In Chapter 3 electromechanic and electroacoustic analogies are presented. This knowledge is fundamental for the analysis and design of electroacoustic transducers. Two analogies: the impedance (force) and mobile analogies are introduced for mechanical systems, whilst only the impedance analogy is presented for acoustical systems. The duality of the two types of electromechanical analogies is emphasized. The circuit fidelity as well as the impedance fidelity for electromechanical systems is also discussed. For further consideration the mobility analogy of electromechanical systems has been chosen. For acoustic systems the impedance analogy is used. In my opinion, this can cause some confusion for inexperienced readers. Using the mobility analogies, the analogous pairs of quantities are: voltage-velocity and current – force. For the electroacoustic impedance analogy the analogous pairs are: voltage-pressure (force per unit area) and current – volume velocity (linear velocity times surface). For complex systems containing three parts: the electric, mechanic and acoustic ones, as e.g. in electroacoustical transducers, between the mechanic part of system and the acoustic one the gyrator must occur. Using the impedance analogy for both parts of the system, a transformer occurs, which is more natural. In the next parts of the book, the Authors avoid the construction of equivalent electrical circuits for complex systems such as loudspeakers in enclosure or earphones. I understand the reason of this dealing but I use consistently the impedance analogy for the analysis of electro-mechanic and electro-acoustic complex systems in my teaching activity because of its unified way of analysis. The Authors present also a lever as the analogous element to a transformer and the change of a waveguide cross section as the acoustical transformer of a mechanical impedance. This consideration should be related to section 8.5.

The next three Chapters (4, 5 and 6) concern electroacoustical transducers. In Chapter 4 the carbon microphone is presented – the oldest one. Next the four-pole theory of reversible transducers is given. Particularly, the reciprocity principle is emphasized. It can be used for an absolute calibration of transducers. In a further part of this chapter, The Authors describe the coupling between the moving part of transducers and the surrounding gas (usually air). This coupling is described by introduction of the radiation impedance. In the last part of this chapter the receivers of acoustical waves – microphones and their basic properties are described as well. The dependence of sensitivity of pressure-gradient microphones on the distance between microphone and source for low frequencies is called in bibliography "a proximity effect". This effect is described in the book but is not named. This Chapter looks to be a bit chaotic. Chapter 5 deals with magnetic transducers. The dynamic loudspeaker, earphone and microphones (ribbon and coil), electromagnetic receiver (earphone) and microphone used in hearing aids and electrostrictive ultrasonic transducers are presented very briefly. The isodynamic principle is not presented. Figure 5.7 explaining the frequency response of loudspeakers is incorrect. In the terms of power or energy quantity levels ten logarithms appear instead of twenty logarithms as for other physical quantities: pressure, velocity, current, voltage etc. Then, for low frequencies, below the resonance, the frequency response of radiated power increases proportionally to the 4th power of frequency, but in a double logarithmic plot it is 12 dB/oct instead of 24 dB/oct. Similarly, the square of velocity increases by 6 dB/oct below the resonant frequency and decreases by 6 dB/oct above resonance (see also Fig. 2.5). As I noticed earlier, the equivalent electrical circuit contains only electrical and mechanical parts and does not contain acoustical ones. The use of a gyrator between the mechanical and acoustical parts would be required for the used analogies: mobile for the mechanical part and force for the acoustical one. In Fig. 5.14 an electromagnetic microphone used in hearing aids is presented. Nowadays, in hearing aids almost exclusively electret microphones are used. The electromagnetic transducers with balanced armature are used often as earphones (in the specific terminology for hearing aids, earphones are called receivers, which has been also pointed out in the book). The construction is identical as presented in Fig. 5.14. In Chapter 6 so-called electric-field transducers are described: piezoelectric, electrostatic (condenser) with the branch of electret transducers. On page 83 the high-frequency condenser microphone is qualified as a dielectric microphone. This is not correct. Although the capsule of a conventional condenser microphone can be used in a HF-microphone, its principle is similar rather to a carbon microphone or other controlled couplers than to the dielectric ones. In HF-microphones the controlled element is the condenser. The change of its capacitance causes frequency modulation of the HF-signal. Of course, this principle is not reversible. It is also worth mentioning that the lower limiting frequency of this microphone is controlled by the hole for static pressure equalization.

The presentation of physical acoustics begins in Chapter 7. The one-dimensional wave equation is derived from three principles: the Euler's equation, continuity equation and state equation. The analogy between an acoustical wave and waves in the electrical transmission lines is shown. The basic solution of the wave equation in the form of progressing and returning waves is presented. The application of this solution in the acoustic transmission line is used for measurements of the reflection and absorption coefficients as well as of the acoustical impedance (Kundt tube). The sound intensity as the vector quantity is defined. In the next Chapter 8 the considerations on acoustic transmission lines are continued. In this chapter the transmission lines with a changing cross section are presented. They are called horns when the change of the cross-section is continuous or stepped ducts, when two or more tubes with different diameters are joined in cascade. For horns the Webster equation is derived, which takes a continuous change of the diameter into account. Two particular cases are presented: the conical and the exponential horns. The phenomenon of dispersion for exponential horn is described as well. The aim of the application of horns is fitting of acoustical impedances in order to improve the efficiency of radiation. This is explained in Fig. 8.6. However, from this Figure the inexperienced reader can conclude that the best fitting, independent of frequency can be achieved for a simple tube. Of course the consideration on the advantage of an exponential horn over the conical one is true. I do not understand the last sentence in section 8.4 (page 111). What the Authors mean by a spherical wave horn? The shape of the wave front is spherical for conical, and the increase of the input resistance is not the steepest one. This increase is steepest for a katenoidal horn, where the shape changes as hyperbolic cosine. Stepped ducts are used as acoustical filters. It could be mentioned that using a chain of stepped ducts the voice channel for speech production can be modeled.

In the next two Chapters, 9 and 10 the radiation of sound and sound sources are described. In Chapter 9 spherical sources are presented, particularly of 0th (monopole) and 1st (dipole) orders. The properties of spherical sources are derived from the wave equation in spherical coordinates. The knowledge of mathematical foundations of this equation is rather advanced, however it is presented in a manner appropriate to the target readers. The basic properties of sources – the directivity and radiation impedance (particularly the resistance) are described in details. In the last part of these chapters, the acoustic antenna of point sources is described. Drew attention to the relationship between the Fourier transform used in signal theory and the method applied for derivation of directional properties of sources. The reciprocity theorem for sound sources (emitters) and receivers is formulated. In Chapter 10 the properties of piston radiators are presented. Piston membranes are complex sources with a continuous distribution of elementary point sources on their surface. The basic formula for the analysis of such sources is the Rayleigh integral. It should be mentioned that in more general cases the source can be described as a continuous distribution not only of point sources but also of dipole sources. The Rayleigh integral is a particular case of the Helmholtz-Huygens integral. It is also the basis of the numerical Boundary Elements Method (BEM) mentioned on page 117. It would be worth mentioning that the Fraunhofer's approximation was used in Chapter 9 for the derivation of directional characteristics of a line array of point sources.

Chapter 11 concerns a few physical phenomena as absorption, dissipation, reflection and refraction. These phenomena play an important role in room as well as in environmental acoustics. The analogy between the transmission of an electric signal in a transmission line with losses and the transmission of an acoustic wave in a lossy medium is shown. The damping coefficient is introduced. Physical phenomena causing dissipation of acoustic waves are presented. The very complex problem of sound propagation in porous media is presented in a simply way. In the next part of this chapter the reflection and refraction (transmission of a wave falling at any angle) of acoustic waves through the boundary of two different media is described. The reflection and absorption coefficients are defined. The presented knowledge is used for the introduction of different kinds of wall absorbers: porous and resonant ones (Helmholtz and membrane).

Chapter 12 provides an introduction to room acoustics. It is entitled "Geometric acoustics and diffuse sound fields". Although this title is in accordance with the content, in my opinion the title "Introduction to room acoustics" would be more inviting for the readers. The idea of rays with propagation rules is presented. The echogram constructed with reflected rays is described as well as the phenomenon of the flutter echo. On the basis of a huge number of ray reflections the diffuse sound field is defined and the formulae for the reverberation time are derived. The critical radius is also introduced. I wish the wave theory of sound field in rooms with the concept of the Schröder frequency was introduced. Thereby the introduction to room acoustics would be complete. The wave theory would be based on theory presented in the previous chapters.

In the next Chapter 13, shows knowledge of sound insulation in buildings. The basic information about structure borne sound – sound in solids – is presented. This is a completely new material for the students. I mentioned earlier that in the book the vibration of continuous solid structures: strings, bars, plates etc. was not presented. This knowledge would be very useful for a better understanding problems presented in Chapter 13. The mass-law is derived and the coincidence frequency is defined. Sound transmission through single-leaf and double-leaf walls is described in details. The weighted sound reduction index is also introduced together with the method of its measurement. The problem of vibration insulation is described. The knowledge is used for the presentation of the idea of a floating floor as the insulation against tapping sounds. The problems presented in this chapter are complex. The way of presentation is simple and convincing.

In the last Chapter 14, some selected problems of noise control are presented. This chapter is a survey of methods used for noise reduction. This Chapter is practical in nature. The properties of noise sources and the influence of propagation conditions on the resulting noise level are described. The knowledge of methods of noise reduction – reduction of the sound power of sources, reduction of noise along propagation paths (noise barriers, mufflers) and reduction at the receiver (individual hearing protectors) are provided. The noise control as a system problem is defined. In this chapter the knowledge given in the previous sections is applied.

In my opinion the book is a very useful tool for students. I pointed out some inconsistencies occurring in the book. They can be easily corrected, and do not influence the worth of this handbook. Although the program of the course of acoustic can be slightly different at different universities, the basic information can be found in the reviewed handbook. In my 40-years practice in courses of electroacoustics for students not specializing in acoustics, I presented additionally the physiology and psychology of hearing and vibrations of solid structures. Of course, the time is not elastic and in the program developed by me, the problems of sound insulation, noise control, and some subsections on reflection, refraction and absorption are missing. However I use this book for my work with foreign students who study acoustics at the Wrocław University of Technology within the Socrates-Erasmus project. I recommend this book as a basic handbook for foreign students and as asupplementary handbook for Polish students.

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