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Book Review

Leo L. Beranek and Tim J. Mellow, *Acoustics – Sound Fields and Transducers*, Elsevier – Academic Press 2012

The reviewed book is a new, expanded and modernized edition of the classical position of the book "Acoustics" published in 1954 and reprinted in 1986. The subtitle: "Sound Fields and Transducers" reflects well the nature of the changes in relation to the original. The chapters concerning sound fields and transducers have been added or significantly expanded and chapters on other subjects, such as noise control, hearing, and speech, have been removed. The chapter about acoustic measurements has been also removed, although some parts of it concerning reciprocity calibration of transducers would be compatible with the concept of the present version of the book. The book consists of 14 chapters. The chapters are divided into parts which are numbered consecutively, independently on numeration of chapters, and sections numbered within chapters. The book contains also three appendices. The scientific level of the book is high and it is designed for advanced readers, e.g., graduate students, and professionals who want to expand their knowledge.

Chapter 1 is entitled "Introduction and terminology". It contains basic information about the history of acoustics, nature of sound, and definitions of basic acoustic quantities. Although the history of acoustics is intentionally very short, it lacks mentioning the name of Ernst Chladni (1756-1827) who introduced the term "acoustics" into the general circulation and was the author of the first handbook of acoustics (Die Akustik, Leipzig 1802). He is called "the father of acoustics". This chapter is an introduction to more advanced topics of the rest of the book.

In chapter 2 the equation of acoustic wave is derived on the basis of Euler's equation, continuity equation, and gas law. The solutions of this equation in one dimension, e.g., in ducts as well as the freely traveling plane, cylindrical and spherical waves are presented. The solutions of the wave equation in three dimensions in rectangular, cylindrical, and spherical coordinates are also discussed. The chapter is well illustrated with numerical examples and figures. However, it also contains some errors. The data in Table 2.1 for the case of "resilient termination" ($Z_T = 0$) are incorrect. The standing wave ratio which is defined as the ratio of maximum and minimum of the pressure (RMS or magnitude) of the standing wave cannot be less than unity. It is equal to ∞, similarly as for rigid termination. This error is caused by an incorrect form of equation (2.57). The modulus of the reflection coefficient should occur in this equation:

$$SWR = \frac{1+|\Gamma|}{1-|\Gamma|}.$$

It is worth noting that the reflection coefficient can be a complex number, and in that case equation (2.57) in the incorrect form is senseless. The absorption coefficient is a quantity which is defined as the ratio of acoustic **power or energy density** absorbed by the termination to the **power or energy density** of the incident wave (see Section 10.6). It cannot be lower than 0 (entire reflection) and higher than unity (entire absorption). Then, its value cannot be equal to 2. The error is caused by the incorrect form of equation without a number between equations (2.57) and (2.58). The correct form is as follows:

$$\alpha = 1 - |\Gamma|^2 = 1 - \left|\frac{Z_T - \rho_0 c}{Z_T - \rho_0 c}\right|^2.$$

In the considered case of resilient termination it is equal to 0.

Chapter 3 concerns electro-mechano-acoustical circuits. The analysis of these circuits using electromechanical and electroacoustical analogies is a foundation for analysis of electro-acoustical transducers, considered as unified systems. Two types of transducers are analyzed in this Chapter: electromagnetic-mechanical and electrostatic-mechanical ones, both being reciprocal. They can work in two directions: transducing the acoustical signal into electrical one (microphone) or transducing the electrical signal into acoustical one (loudspeaker). There are many types of transducers. They can be divided into two main parts: reciprocal and not reciprocal. The second group includes the electron-, carbon-, and piezoresistive transducers. The first group can be divided into two sub-groups: transducers which operate with a magnetic field and transducers which operate with an electric field. The first group includes transducers with a moving wire, also called dynamic or electrodynamic transducers, transducers with a moving armature, also called electromagnetic and magnetostrictive ones. The second group includes electrostatic or condenser transducers and piezoelectric transducers. Then, the terminology used in this chapter can be confusing for the readers. The presented transducers are dynamic type rather than electromagnetic one and piezoelectric type rather than the electrostatic one. This mismatch of terminology for transducers occurs also in the next chapters.

Chapter 4 consists of two main parts. In the first one, the acoustic elements: mass, compliance, resistance, transformed are presented. In my opinion, this part could be included into Chapter 3, where the electro-mechanic-acoustical analogies are described. Part XIV (acoustic losses) could be also included into Chapter 3. The second part of Chapter 4 concerns the sound sources: monopole and dipole, a pulsating and oscillating sphere, arrays of point sources, and pistons: free, in an infinite baffle, and free disk radiating from one side. The connected problems, such as directivity and radiation impedances, are also included. The place for these topics is in my opinion in Chapter 2. In my opinion, the more clear structure of the book would be as follows: Chapter 2 with the analysis the of sound sources, Chapter 3 with acoustical elements but without transducers, and instead of Chapter 4 in its present form – a new Chapter 4 with a detailed analysis of transducers, including different types of reciprocal and non-reciprocal transducers.

Next chapters of the book deal with electroacoustic transducers: microphones, loudspeakers, and loudspeaker systems. In Chapter 5 microphones are analyzed. The general types of microphones: pressure, pressure-gradient, and combined ones are described. The actual constructions of microphones are presented. They are: dynamic moving coil microphone, electrostatic (capacitor) microphone, ribbon microphone. A mismatch of the terminology appears. Both moving coil and ribbon microphones are dynamic (with a moving wire) rather than electromagnetic (with a moving armature) ones. The terminology for electrostatic microphones is correct here. There is no analysis of the electret microphone, it appears only in Chapter 8.

Chapter 6 concerns dynamic loudspeakers. It contains a detailed analysis of their properties using the theory developed by Thiele and Small. The design rules of loudspeakers are also presented. The information about directivity, transient behavior, and nonlinear distortions in loudspeakers is also included.

The next chapter, No. 7, is a continuation of Chapter 6. It presents loudspeaker systems: loudspeaker enclosures, their analysis, properties, and design rules, as well as the multiple drive units with concentric drive and crossover networks. The analysis of loudspeaker enclosures is based mainly on Thiele-Small theory. The considerations about damping materials used in enclosures are very useful.

Chapter 8 concerns electroacoustic transducers used in cellular telephones. They are specific transducers. The loudspeaker does not radiate into free space, but directly to the ear of the user. Such loudspeakers are used not only in cellular handsets but also for hearing of music by mobile users or by professional sound engineers or, e.g., in hearing aids. Such loudspeakers are called "earphones" and their construction and method of analysis and design are different from those of direct radiator loudspeakers. In the second part of Chapter 8 the properties of electret microphones are described. Electret transducers are classified as condenser or electrostatic ones. In these transducers the bias is delivered by the electret materials, which produce permanent electric field. The difference between conventional condenser transducer and the electret one is the same as in the electromagnetic transducer polarized with an electric current delivered from a power supply and with a permanent magnet. In my opinion, the presented in Chapter 8 analyses of both loudspeaker and microphone transducers are a little superficial, however, it is a first attempt of presenting the acoustics of cellular phones in a handbook.

In Chapter 9, the horn loudspeakers are described. The efficiency of conventional direct radiator loudspeaker (and loudspeaker systems) is low and equals ca. 1%. In small spaces this value is sufficient for production of the required sound pressure level, but for large spaces such as concert halls, auditoria, sports arenas, etc., it would cause a high power consumption. In horn loudspeakers, the horn causes fitting of acoustical impedances between the source (vibrating membrane) and receiver (free space). The horn plays the role of an acoustical transformer. Then, the horn loudspeakers are usually called "indirect radiator loudspeakers". In Chapter 9 the construction and design rules of horn loudspeakers are presented. Various kinds of horns are described: parabolic, conical, exponential, and hyperbolic ones. Exponential horns are the most important ones. It is worth mentioning that the exponential horn is a particular case of hyperbolic one, for α-parameter equal to 1. The hyperbolic horn for $\alpha = 0$ is called a "chain" or "hyperbolic cosine" horn. The problem of bends in horns is also considered in the book. It has a practical significance, because folded or bent horns are often used in order to reduce their dimensions.

In Chapter 10 Authors come back to sound fields. The title of this chapter is "Sound in enclosures". It is divided into two parts. In the first part (according to Author's numbering – Part XXX) sound fields in small regularly shaped enclosures are analyzed. The term "regularly shaped" means in this case rectangular enclosures. The term "small" concerns dimensions of the enclosure which is small in comparison to the wavelength. The examples of such enclosures are loudspeaker cabinets or small rooms (e.g., control rooms for recording studios) in the low frequency range. The problems of enclosure resonances and distribution of sound pressure levels for resonant frequencies are considered. The influence of losses is also discussed. In the second part of Chapter 10, sound fields in large enclosures are considered. Large enclosures are simply rooms in medium and high frequency range. Reverberation is the main subject of discussion in this part. The sound strength is defined. The SPL for speech and music in rooms is also discussed. Geometrical methods for acoustic field determination in large rooms are missing in my opinion.

In a short Chapter 11 problems of rooms for loudspeaker listening are presented. The design rules are determined.

Chapter 12 contains a derivation of acoustic fields produced by sources of cylindrical and spherical shapes as well as sound fields which are result of scattering of the plane or a spherical wave by cylinders or spheres. The information contained in this chapter would be useful for considerations about radiation by loudspeaker membranes of non-planar shape. The knowledge about scattering would be useful, e.g., for calculation of diffraction correction in microphones. Thus, in my opinion, this chapter should appear before chapters about loudspeakers and microphones.

In Chapter 13 the advanced radiating and scattering structures are presented. The Huygens-Fresnel principle is considered and the Kirchhoff-Helmholtz and Rayleigh integrals are discussed. The Green functions in most popular types of coordinates: rectangular, cylindrical, and spherical are derived. On this basis radiation from different structures is determined. The directional patterns and radiation impedances of presented structures are calculated. Chapter 13 contains mainly theoretical considerations and only a few practical examples. Boundary integrals are the basis for the numerical method of computing of sound fields called Boundary Element Method (BEM). This method is often used for computing of sound fields radiated by sources of complicated, irregular shapes as, e.g., a loudspeaker in a cabinet. I wish the BEM were presented in the book as well.

Chapter 14 is last in the book. It presents the state variable analysis of the circuits. This method is usually applied for analysing electrical circuits and electronic systems, but it can be also effectively used for loudspeaker systems. The construction of state equation is presented in details. Such elements as transformers or gyrators, which can appear in equivalent circuits of loudspeaker systems, can be also included. The separate node, which represents the radiated acoustic pressure, allows for calculation of the frequency response (acoustic pressure vs. driving voltage) of an analyzed system.

TAdvanced considerations about electrical filters and mathematical functions used for different analyses in the book appear in Appendices.

The book contains two types of knowledge: a very practical knowledge about electro-acoustic transducers, particularly loudspeakers, loudspeaker systems, and microphones and a very theoretical knowledge about sound fields, sound radiation, and scattering. Both types of knowledge occur in the book not always in a logical order. As it was mentioned earlier, the book is intended for experienced readers, who are able to choose information they need. The book contains a lot of information. Unexperienced readers, who would use the book as a handbook of acoustics, should choose only some parts of the book, e.g., Chapters 1–7 and 9, 10.

Taking into account that readers of "Archives of Acoustics" are familiar with acoustics and electroacoustics, I can recommend them the book "Acoustics – Sound Fields and Transducers" by Leo Beranek and Tim Mellow for their library. They can find in the book detailed information or use it for preparing lectures for students.

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