Acoustics of Small Rooms
Mendel Kleiner and Jiri Tichy
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The acoustics of small rooms has been of interest since the dawn of recording in the late 19th century. It became a field for study for about 100 years ago after the development of broadcast radio and concerted research in the 1930s. Some seminal papers by Morse and Bolt (Rev Modern Physics, v16, 1944) and Bolt (JASA, v18, 1946) appeared after World War II and many thereafter. The term "size matters" is one that is true in acoustics, and small rooms have, when wavelengths are similar to, and greater than the dimensions of a room simple geometric and statistical analysis breaks down.

Mendel Kleiner and Jiri Tichy, Professors Emeritus at Chalmers University of Technology and The Pennsylvania State University, respectively, in *Acoustics of Small Rooms* have produced a useful and up-to-date guide for serious students and practitioners of small room design, as well as the end-users of such rooms.

There are many texts that address room acoustics, but these focus, and have an emphasis, on the acoustics of larger rooms, such as concert halls, opera houses, auditoriums and the like, and there are many texts that deal with perceptual acoustics (psychoacoustics). The concise and logical layout in *Acoustics of Small Rooms* allows the reader to access the information in these many tests in one place and this book presents the mathematical physics, material analysis, human factors and audio engineering, and computer and measurement techniques necessary for understanding sound fields and their perception in small rooms.

The physics of small room sound fields is presented first in a chapter of the same name. In addition to the usual derivation of the wave equation for free waves and a review of acoustic metrics and analysis techniques, the authors derive the wave equation for forced waves — necessary for small rooms in which sound systems are utilized. This chapter, and others, assumes a working knowledge of calculus including complex operators.

Next, the authors look at the sound fields in enclosures. Wall impedance and the boundary conditions this imposes on the eigen-function solution to wave equation are key to the development of modal density, modes and forced waves. In addition, the statistical parameters of the room, such as reverberation, are presented.

In the chapter titled "Geometrical Acoustics", the authors discuss transient (impulse) sounds that are produced by many sources and the hearing system's response to these sounds, ray tracing, diffraction, surface dimensions, Fresnel zones and the response (build-up and decay) of real rooms to impulses.

A key design element in many rooms is absorption and the mechanisms for wall treatments which are covered next. The discussion for porous, resonators and complex absorbers is detailed with both the equations that describe the physical performance of the devices, along with many illustrations. As with some of the chapters in the text, the analysis is rigorous. Another important element in room design in general, and at times overlooked in small rooms, is diffusion of the sound field by the room boundaries — which when used correctly can be an important part of the room design. The chapter titled "Diffusion" presents a review of the basic principles of diffusors, techniques for the measurement of scattering and diffusion, design of these elements (including the effect of fins), and the absorption characteristics of diffusors.

With the basics presented in the previous chapters, the next three chapters, The Ear, Psychoacoustics, and Spatial Hearing, give the reader an excellent introduction to how humans hear and how they perceive what we hear. Sometimes this aspect is overlooked in the design process.

The tougher parts of small room design are covered in the next chapters. The chapter on rooms with sound systems looks at how the sound field can be analyzed in two parts to better understand the interaction between the room (which is basically a filter) and the loudspeakers. For low frequencies loudspeaker placement and mode damping are important. For the mid- and high frequencies reflections, reverberation, absorption and diffusion are important.

The text next takes a more detailed look at low-frequency sound field optimization and the difficulties in achieving same — modes, modal density and modal overlap – and two useful implementation techniques – wave modification and room geometry.

Now, over the years that sound equipment and room acoustics for sound reproduction have been studied, some general characteristics for successful design have been codified. ITU-R BS.1116-1 and IEC 268-13 are two of the more common ones which specify symmetry (for stereophonic use) and the reduction of strong reflections. The near anechoic, live-end-dead-end, reflection free zone, and controlled image design protocol for control rooms are reviewed as well as suggestions for home systems.

The final chapters are devoted to small room design for voice and music practice, modeling of room acoustics and measurements. For voice and music practice rooms, the design factors include the effect

of instrument sound power in a small space and the risk of hearing impairment, background noise levels, similarity between the rehearsal space and the performance space, reverberation time, geometry and diffusion, and the problems when remodeling an existing space or spaces.

The chapter on modeling discusses some physical and computer modeling techniques, and since the three models – geometrical, statistical, and wave mechanical – each cannot span the full frequency range, so especially for small rooms, the frequency range of interest is split into low and high frequency parts. The pros and cons of physical (scale), numerical models (BEM, FEM), and auralization are reviewed.

The last chapter takes a look at measurement — an essential part of acoustic engineering, or as Lord Kelvin said "To measure is to know" and "If you cannot measure it, you can not improve it." Acoustic metrics such as sound pressure, particle velocity, sound intensity measurement using a microphone or microphones, measurement sources such as loudspeakers, some of the derived metrics (distortion and noises), uncertainty (yes — there is uncertainty in audio measurements), filters, weightings, transducer noise, measurement below the Schroeder frequency, and more are discussed in this clear and concise chapter.

Each chapter has a list of the references noted in the text and shows the depth of research by the authors. *Acoustics of Small Rooms* is a useful reference, tutorial and guide for the designer, builder and end-user of small rooms.

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