

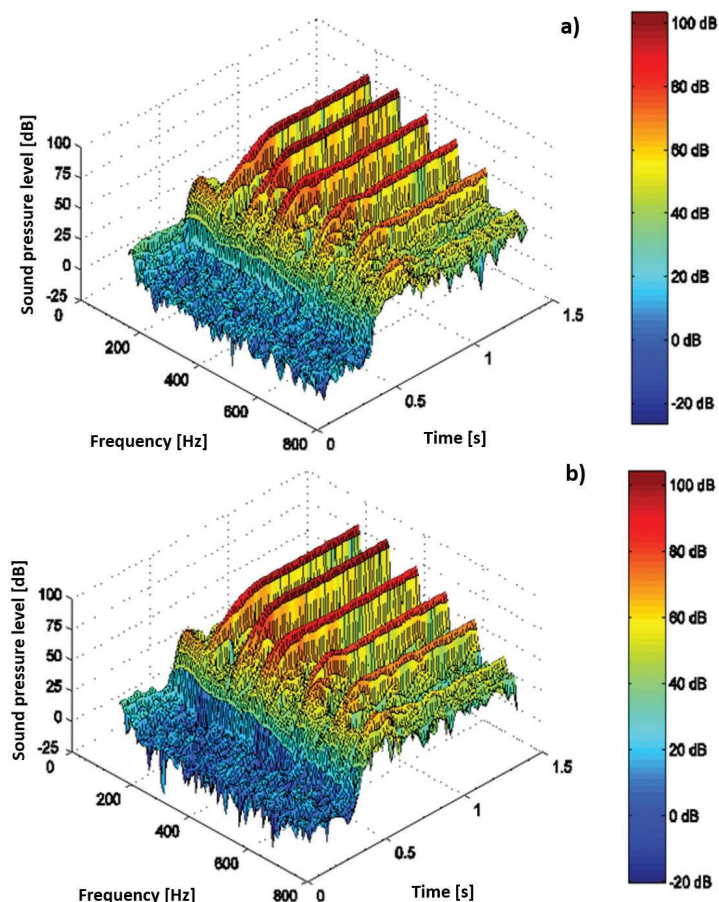


Figure 10. A 3-D representation of the analyzed attack transients of the Diapason G pair of pipes (same as shown in Figure 9). The graph shows the onset of the pipe sound and thus how the partials of different frequencies are built up in time. **a:** Made of plain metal (tin-lead alloy). **b:** Made of zinc.

The explanations given above show that several different mechanisms influence the steady sound of pipes. On the other hand, even the most complicated features could be assigned to the measurable and understandable physical properties of flue organ pipes.

The research results in flue pipe acoustics can be adapted in the applied research for supporting the daily work of organ builders. The next section presents an example of the trends in applied research.

Sound Design of Chimney Pipes

Chimney pipes are semiopen flue organ pipes whose resonator consists of two main parts: a straight cylindrical main part and a shorter and thinner chimney attached to its top (Figure 11, top left). The length and the diameter of the chimney may vary, and this makes it possible for the organ builder to adjust the timbre. For example, chimney pipes in baroque-

style pipe organs should have a sound rich in the pure fifth (third harmonic), while romantic-style instruments require more major third (fifth harmonic) in the sound. To be able to fulfill these requirements, special design rules are needed for determining the dimensions of the pipes so that the desired character of the sound can be achieved. The process of determining the appropriate geometrical dimensions of organ pipes with the purpose of attaining a predefined timbre is referred to as “sound design.”

The chimney pipe construction was studied by different researchers, most notably Helmholtz. His conclusion was that to reinforce the fifth harmonic in the sound, it is best to have a chimney with a length two-fifths of that of the main resonator (Helmholtz, 1954). Apparently, in a more recent examination, the configuration proposed by Helmholtz turned out to be the least favorable one (Kokkelmans et al., 1999). In the study initiated by the organ builders and performed by the authors of this article, a novel methodology for the sound design of chimney pipes was established and implemented in a software tool.

The idea of the proposed sound design approach is to tune the eigenfrequencies of the resonator so that they become coincident with the frequencies of predefined harmonic partials of the sound (Rucz et al., 2013). When a harmonic partial overlaps with an eigenfrequency, the corresponding eigenmode gets excited very efficiently and hence the amplification of the harmonic can be expected.

By computer simulation, the so-called input admittance is calculated. The peaks of the input admittance correspond to the peaks of eigenresonances. It is important that the peaks of the red curves in Figure 11 match the partial to be enhanced.

The measured steady-state sound spectra are displayed in Figure 11a-c. In each diagram, the sound pressure measured at the pipe mouth and the calculated input admittance are displayed by the black and red lines, respectively. Figure 11a shows the reference pipe with the amplitude of the first seven harmonics, indicated by the numbers on the blue background. The reference pipe has a strong fundamental component in its sound while the higher harmonics are very weak. Figure 11b,c displays the results of the chimney pipes optimized for the third and fifth harmonics, respectively. The numbers on the green background indicate the amplification of the targeted harmonic partial compared with the levels measured in the case of the reference pipe. The num-

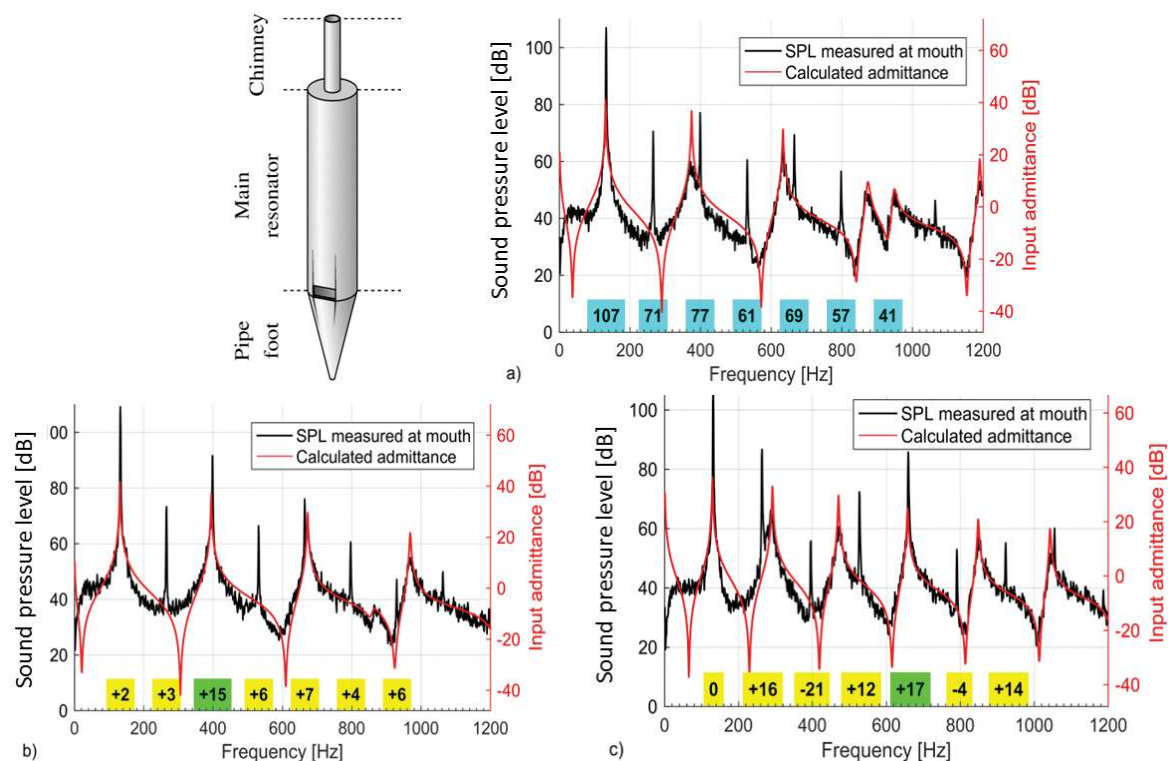


Figure 11. Top left: sketch of a chimney organ pipe. **a–c:** Measured spectra (black) and calculated input admittance (red) of the experimental chimney pipes. **a:** Reference chimney pipe design. Numbers on the blue background are the amplitudes of the first seven har-

monic partials. **b:** Optimized design enhancing the third harmonic (pure fifth) by 15 dB. **c:** Optimized design enhancing the fifth (major third) by 17 dB. Numbers on the green and yellow backgrounds show the relative levels of the harmonics compared with the reference pipe.

bers on the yellow background show the same changes in the levels of the other harmonics. As can be seen, the optimized resonators can enhance the targeted harmonics by more than 15dB while keeping the fundamental frequency constant. This amplification can be considered substantial if one takes into account that the experimental pipes only differed in the geometry of their resonators.

Conclusions

The intention of the authors of this paper was to demonstrate that the research on organ pipes leads to a better understanding of how they function. Moreover, research can provide scientific explanations to support or refute strong established beliefs of organ builders and, last but not least, can provide new scientific results and tools for further improvement of the art of pipe organ building.

Biosketches



Judit Angster is a physicist and has been working at the Fraunhofer Institute of Building Physics IBP in Stuttgart, Germany, since 1992. She established and has been head of the Research Group of Musical Acoustics/Photoacoustics. She lectures on acoustics at the University of Stuttgart

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