Sound power determination in a reverberation room

The sound power of three different noise sources should be determined in one-third octave bands in the frequency range from 100 Hz to 10 kHz. Source 1 is a Brüel&Kjær (B&K) 'Sound Source' of type 4205, a loudspeaker driven with pink noise. This is a high-impedance source, which means that its volume velocity is essentially independent of the acoustic impedance load of the sound field. Source 2 is an aerodynamic source (a fan), B&K's 'Reference Source' of type 4204. This source is of low internal impedance, which means that it tends to keep the sound pressure constant rather than the volume velocity. Source 3 is a dipole consisting of two loudspeaker units driven in antiphase.

Preparation: Read chapter 8 in the book carefully, especially sections 8.3, 8.4 and 8.5 (section 8.5 is particularly relevant).

Sound power determination with the diffuse-field method relies on the relation between the total acoustic energy in a room in steady state, the losses of the room, and the sound power emitted by the source that generates the sound field,

$$P_a = 13.8 \frac{V\langle\overline{p^2}\rangle}{\rho c^2 T_{60}}\left(1 + \frac{S\lambda}{8V}\right)$$

where P_a is the sound power of the source under test and $\langle\overline{p^2}\rangle$ is the room-averaged mean square sound pressure in a given one-third octave band, V is the volume and S is the surface area of the room, T_{60} is the reverberation time of the room in the frequency band, ρ is the density of air, *c* is the speed of sound, and λ is the wavelength at the center frequency of the band. The (small) factor in parenthesis on the right side of the equation is the 'Waterhouse correction', which accounts for the additional sound energy in the room associated with the increase of the sound pressure near the boundaries.

The reverberation time of the room is measured using the B&K measurement system 'PULSE'. This instrument can be programmed to generate white or pink noise for a given duration of time, turn off the noise signal and record the sound pressure during the decay in one-third octave bands; it can average a number of such reverberation decay functions, and calculate the reverberation time from the rate of decay over a specified interval. The reverberation time of the room should be determined from decay functions averaged over two loudspeaker positions and at least three microphone positions for each loudspeaker position. For each combination of source and receiver at least five decays should be averaged. It is important to measure the reverberation time accurately for a correct estimation of the sound power.

The acoustic energy in the room generated by the source under test is estimated by integrating the signal from a microphone on a rotating boom in one-third octave bands using the frequency analyzer. Note that the analyzer measures the mean square pressure (in squared Pa), not the root mean square pressure.

1) The sound power of the three sources placed on a reflecting plane is estimated using source positions on the floor far from the walls. At low frequencies the sound power output depends to a certain extent on the position in the reverberation room, and the accuracy of the measurement will be improved by averaging over several source positions (average over three positions – you can possibly notice that this can affect the averaged SPL at low frequencies).

2) Additionally, it should also be examined how the sound power output of each of the three sources is systematically affected by placing the source near a wall (i.e. changing the radiation impedance). To examine this effect, one can compare the proper sound power estimates (where the measurement is conducted far from the walls), with the estimates obtained when the source is close to a wall (i.e. the sound power output of the sources is affected by the different radiation impedance).

Note: The volume of the reverberation room is about 245 m^3, and the surface area is about 240 m^2. The microphone used in determining the sound energy in the room is a so-called pressure-field microphone of type B&K 4192. Sound pressure measurements in a reverberation room should be corrected by adding the following (negative) random-incidence correction to the result:

Center frequency (kHz)	4	5	6.3	8	10
Correction (dB)	-0.1	-0.2	-0.6	-1.0	-1.6

Because of using a high density windscreen, which attenuates the high frequencies notably, the following additional correction should be included (added):

Center frequency (kHz)	1	1.25	1.6	2	2.5	3.15	4	5	6.3	8	10
Correction (dB)	1.4	1.4	1.4	1.7	1.8	1.8	2.2	2.4	3	3.3	3.6

Report

The results of all sound power measurements should be presented in dB re 1 pW in one-third octave bands. Present and discuss the various sound power estimates, with particular regard to the effect of placing the sources far from all walls and near a wall.

It makes sense to present the results from this lab exercise and the *Sound intensity* exercise in one single report, since, obviously, the estimated sound power of the various sources should not depend on the measurement technique. The report should be submitted two weeks after the day of the last of these two exercises.

For guidance: expected length (considering that two lab exercises are presented in one combined report) is approx. 7-10 pages (Intro 0.5 p; Theory 1-2 pp; Setup 1 p. Results & discussion 4-7 pp.; Conclusions 0.5-1 p.). The report should be *complete* and concisely written.

References

F. Jacobsen and P. M. Juhl, *Fundamentals of General Linear Acoustics*, John Wiley and Sons, 2013