The Experiment

Hardly anything shapes the auditory impression as strongly as room acoustics. We explain the background and suggest solutions to common problems.

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Karl Kunstkopf (name changed) is dissatisfied with the sound of his system. First he tries to tune it, replaces the cables, the power cable and the rack. When all this does not lead to success, he invests a four-figure sum in new speakers – with frustrating results. It still sounds diffuse, the basses rumble and the trebles bite. Quite a few HiFi fans suffer something similar and finally say goodbye to their beloved hobby in frustration. However, the solution to the problem is often quite obvious: if a high-quality system plays badly, then almost always the room acoustics are to blame.

Although the room has a much more drastic effect on the listening impression than, for example, speaker- or power cables, this topic is still gravely underestimated by many hi-fi fans. It seems rather obvious, because every room has its own characteristics. High-quality speakers, amps and players might be tuned (approximately) linearly, the sound waves are, however, influenced, reflected, amplified or attenuated by the room on their way from the loudspeakers to the listener.

But how to create a favorable room acoustics you ask? In order to demonstrate

this, we first deliberately start under bad conditions, which we then improve step by step. The starting point for our experiment is the situation immediately after moving into a new flat. The rectangular room, 28 square meters or almost 72 cubic meters in size, is almost entirely empty. As a test system we have put together a good mid-range chain consisting of the CD player/integrated amplifier combination "M3 SCD/M5 SI" from Musical Fidelity and two Canton Vento 896 speakers.

As the first listening example we choose Rodrigo Y Gabrielas version of the rock classic "Stairway To Heaven" for two acoustic guitars: under good listening conditions a music that can carry you away. However, here it seems unpleasantly garish, with especially the high tones being bity, so that the dramatic increase towards the end becomes an ordeal. No, this "Stairway To Heaven" turns out to be a gravel road to hell instead. Dave Brubeck's jazz standard "Take Five" feels hardly any better. Saxophonist Paul Desmond seems to play in a tiled bathroom. Rarely have we experienced such resonance. Bass and piano sound queasy, and the rhythm figure that drummer Joe Morello celebrates on the cymbal is far too loud. Franz Liszt's "Hungarian Rhapsody No. 2", conducted by the legendary Leopold Stokowski, doesn't ignite, so mushy is the sound of the orchestra that the racy "gypsy melodies" seem to mumble in the canyons of Transylvania. Also, the strings are too sharp in the high trebles. AC/DC's hard rock anthem "Back In Black" is almost physically unpleasant: while the basses roar, crackling voices and guitars whip the drumheads: horrible like a tinnitus.

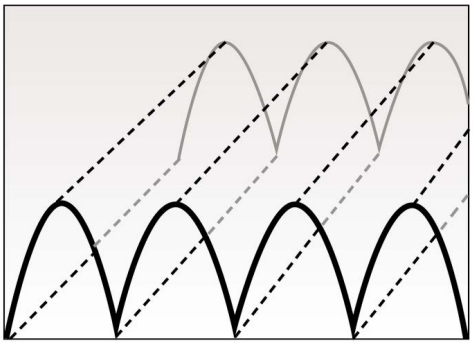
The graph created by measuring the room acoustics confirms the terrible impression: four peaks at 45, 67, 90, and 114 Hz stand for room modes with about 10 decibels higher level than in the mid and high frequency range. This means that these bass tones are perceived as twice as loud, with an unpleasant humming effect. Another disturbing factor is the long reverberation time, which is a full second at 64 Hz and makes the sound appear uncomfortably diffuse – 0.4 to 0.6 seconds are considered pleasant for a room of this size.

The reverberation times also have a negative effect in the midrange and especially

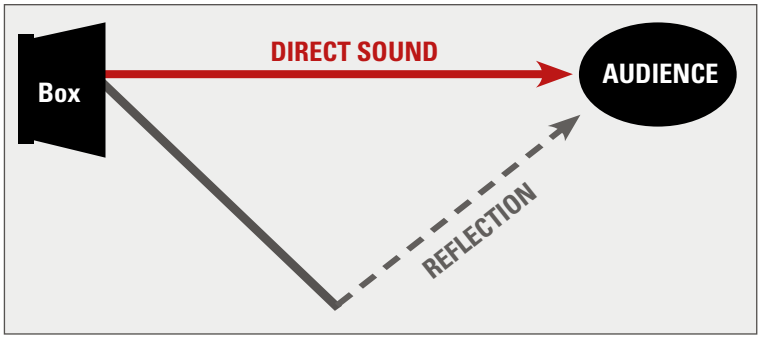
„Stairway To Heaven“ in bad acoustics: a gravel road to hell

1 A situation like directly after moving in: the room is empty. Acoustically this has a highly problematic effect.
2 When furnished, the room sounds better, but speakers should not be placed directly on the wall.
3 An interesting option: rotate the system and listening position 90 degrees in the room.

in the high-frequency range. Although the waves are significantly shorter here, so that they do not "stand" between the walls, direct sound that is too strongly obscured by reflections discolors instruments and voices. In the worst case, the sound becomes really sharp,



As „standing waves“, room modes in the bass range cause an unpleasant roar.



which can be traced back to flutter echoes. These occur when sound waves are repeatedly thrown back and forth between walls.

So far, so bad. To get a grip on the enemies of good room acoustics – room modes, early reflections and too long reverberation times – we have two main weapons: absorption and diffusion. Without absorption (damping), a sound once emitted would theoretically wander around the room for an infinitely long time.

At first we concentrate on the high frequency range, because the parquet floor, the windows and the plasterboard walls reflect the treble sound components very strongly. Since high frequencies are short, materials with fine-pored structures are suitable for damping. In our case, a sofa and a dense, fluffy carpet between the speakers and the listening position serve this purpose to dampen the first reflections.

Similarly important is diffusion, because diffusely scattered, the reverberation does

If the wavelengths are much smaller than the dimensions of the room, sound propagated by the loudspeaker is either absorbed or reflected (as in the picture on the left). Early reflections arrive at the listener after the direct sound and can discolor the music.

GLOSSARY

Frequency
Indicates the number of oscillations of a signal per second, unit is Hertz (Hz), 1000 Hz = 1 kHz. The higher the frequency, the higher the sound is perceived. The human ear can hear frequencies from about 20 to 20,000 Hz. Long waves are perceived as deep tones, with increasing pitch the waves become shorter and shorter..

Room modes
If integer multiples of half the wavelength fit exactly between two walls, these act like resonators. Example: at a frequency of 43 Hz, the wavelength is eight meters. At a wall distance of exactly four meters – regardless of the length, width or height of the room – this frequency is dramatically amplified. These room modes („standing waves“) cause „booming“ in the bass range.

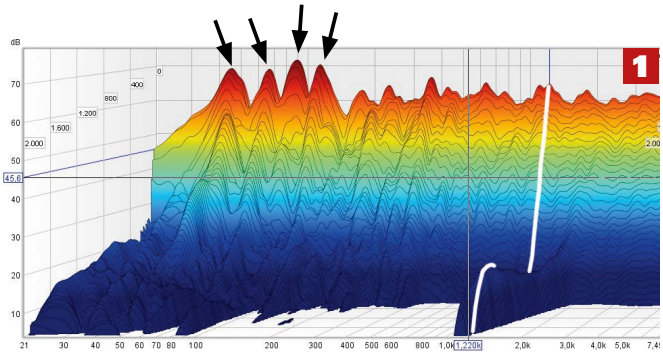
Early reflections
When sound hits surfaces and objects, a certain part of the incoming sound energy is reflected. If early reflections at the listening position superimpose the direct sound too much, the sound image can change color. Especially unpleasant are flutter echoes that occur when a periodic sequence of individual reflections is thrown back and forth between two walls.

Absorption
Another part of the emitted sound energy is absorbed by surfaces and objects (absorption) – which is a blessing, because you get problems with room modes, early reflections or too long reverberation times under control. High, short-wave sound components are attenuated by materials with a porous, open, fine structure (carpets, curtains, foams, etc.). In order to attenuate deep, long-wave sound components, large-volume absorbers such as closed cabinets are required.

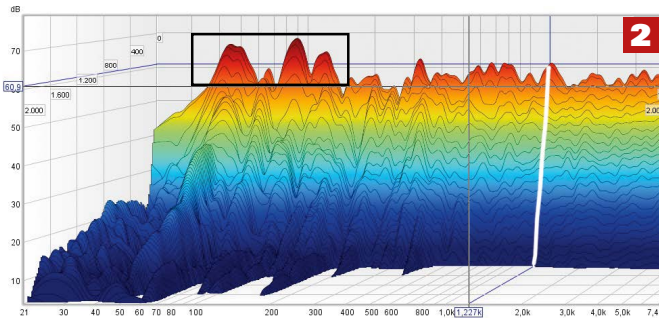
Helmholtz resonator
Resonator with cavity, which withdraws energy in the bass range by means of an opening in order to combat room modes (see above). Usually limited to narrow frequency bands.

Diffusion
When sound hits objects that have a fine structure in the order of the wavelength, the sound of the corresponding frequencies is scattered in different directions, i.e. diffusely. A high diffusion is necessary to create a uniformly mixed sound field in which no isolated reflections can be perceived as disturbing.

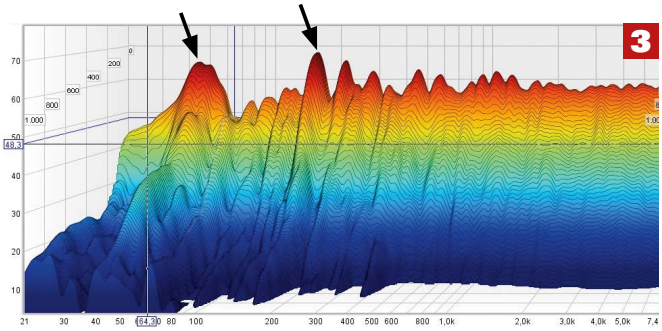
Reverberation time
Defined as the time that elapses in a room after the sound source is switched off until the energy of the sound event has dropped to one thousandth of the initial sound pressure level. The acoustically ideal reverberation time depends on the size of the room: the smaller the room, the shorter the reverberation time should be. If the reverberation time is too long, overlapping will occur and the sound will smear.



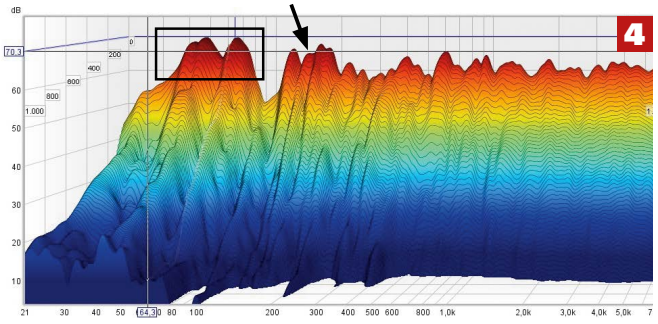
Situation 1 (empty room/bad speaker placement): four peaks at 45, 67, 90, and 114 Hz (arrows) stand for room modes with about 10 decibels higher level than in the mid/high range from about 300 Hz. The reverberation time at 1.2 kHz (white line) is an extreme two seconds.



Situation 2 (furnished room/bad speaker placement): at the problem frequency of 1.2 kHz, the reverberation time has dropped to 0.8 seconds (white line), but the bass range (rectangle) continues to cause problems.



Situation 3 (furnished room/favorable speaker placement): whereas the entire bass range below 140 Hz was previously problematic, there is now only one distinct room mode at 44 Hz (left arrow) and a smaller one in the fundamental range at 157 Hz (right arrow).



Situation 4 (furnished room/90 degree rotation): the mode at 157 Hz (arrow) has weakened, but the middle bass range between 40 and 100 Hz (rectangle) has deteriorated.

not consist of single, sharp reflections, but of many, which decrease evenly in intensity. In other words, "bad" sound components are made "harmless" by being broken down via diffuse reflectors into as many small components as possible and scattered in different directions. In order to achieve a uniformly mixed sound image, we use a shelf in which the books are deliberately "sloppily" sorted, because uneven edges promote this effect; to a lesser extent, houseplants also appear diffuse – the larger their leaves, the greater the effect.

Does this help anything? Yes! The brass players in the "Hungarian Rhapsody 2" and the bass and drums in the "Back In Black" continue to cause big problems. On the other hand, the drums cymbal in "Take Five" doesn't buzz as intrusively as the mid and high frequencies sound much more pleasant. The measurement proves why: if the reverberation time at 1.2 kHz in an empty room was an incredible two seconds, the furniture has reduced it to 0.8 seconds – a huge step forward in terms of a more pleasant sound image.

But there's more to it than that! Especially since we have violated well-known hi-fi rules when setting up the loudspeakers so far. We had placed the two Canton Vero 896 far too close to the wall directly in the corners of the room. Because the bass is jammed there, it is exaggerated, which inflates and smears the lower frequencies. Since the speakers were too far apart, the locatability of voices and instruments had also suffered. We corrected these two points and angled the cantons less in the sense of a bigger sound panorama. In addition, we placed three aluminum cylinders from Acapella under each of the speakers, leading to significantly less bass vibrations being transmitted to the floor.

The measurements are promising: while the entire bass range below 140 Hz used to be problematic, there is now only a large bump at 44 Hz. The reverberation time at 64 Hz has also decreased slightly (from 0.9 to 0.8 seconds). We can cope with the fact that we have negotiated an increase at 157 Hz, which was not there before. Indeed, the

STEREO engineer Uli Apel (right) presents the results of the room acoustics measurements to editor Andreas Kunz.

The reverberation time has dropped: a huge step forward in terms of sound quality.

effect of absorption and diffusion is striking. "Take Five" is much more transparent, which also applies to "Hungarian Rhapsody 2", even if the sound in the orchestral tutti continues to smear; even "Back In Black" now sounds tighter and less poisonously sharp. For the first time we have a listening constellation that is between bearable and acceptable. And with little effort: incredible what a proper loudspeaker positioning can achieve!

In living or listening rooms, one usually tends to place the speakers on the narrower wall. However, in our 6.50 by 4.30 meter room we were forced to place the sofa almost in the center of the room. If it had been placed on the wall opposite the system, the distance to the loudspeakers would have been much too big. Too many reflections would then have overlaid the direct sound component, which would have resulted in a considerable loss of definition and locatability of the auditory impression. In this respect, it is worth trying to let the loudspeakers play from long to long side of the room instead.

A comparison of the measurement graphs shows an uneven picture: The room mode at 157 Hz has weakened, while the middle bass range rather seems to have worsened. The same applies to the listening situation. While in "Stairway To Heaven" the two acoustic guitars by Rodrigo Sánchez and Gabriela Quintero are now more filigree in quiet

TIPS FOR IMPROVING ROOM ACOUSTICS

Distrust design rooms

Spartan rooms with tiles and smooth aluminum and glass surfaces are usually acoustically problematic. It sounds better with furniture and sound-absorbing or scattered objects on the floor/ceiling and walls.

Dampen reflections

In order to attenuate the first reflections of the floor in the high frequency range, you should lay a carpet between the speakers and the listening position. If reflections in the high frequency range are too strong, they can be attenuated by tapestries, or curtains in front of windows.

Get the basses under control

More problems than the high-frequency range are usually caused by the bass range. In order to dampen the energy-rich deep waves, large-volume absorbers such as closed cabinets or room acoustic elements are required. Especially the acoustically problematic room corners, where several pressure-increasing edges collide, should be defused.

Chaos provides good sound

Irregular surfaces and edges improve diffusion. When equipping CD, plate and book shelves, homogeneous end edges should therefore be avoided. Large-leaved green plants and woodchip paper (instead of smooth plastic wallpaper) support this effect.

Find the right listening position

Too close to the speakers the sound image decays, too far away the differentiation can suffer due to overlapping reflections. In a rectangular room, it may be a good idea to have the speakers play from the long side to the long side.

Rearrange the speakers

Since most loudspeakers also radiate to the rear through bass reflex ports, they should usually be moved away from the wall in order to avoid excessive bass. Experiment with the distance between the speakers and their angling.

MATERIAL EDUCATION: WHAT CAUSES WHAT IN ACOUSTICS?

FLOORS

Parquet: Hard reflective
Carpet: Swallows high frequencies
Tiles: Very hard reflective, high reverberation time in tiled rooms
Linoleum: Reflective for low and medium frequencies
Screed: Reflective for low and medium frequencies

WALLS/CEILING

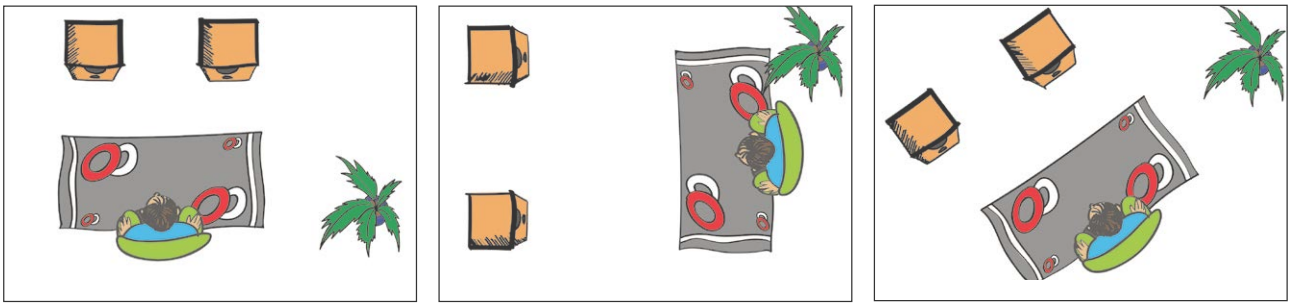
Concrete, lime sand and brick: Reflective for low and medium frequencies, depending on degree of porosity treble absorber
Gypsum: Reflective for high frequencies; with an air gap behind, it becomes an absorber for low frequencies
Plaster: Hard reflective for low to medium frequencies, depending on the porosity of the finish.
Wood paneling: Reflective for high frequencies; with an air gap behind, it becomes an absorber for low frequencies
Woodchip wallpaper with masonry: Reflective for low and medium-high frequencies, depending on degree of porosity treble absorber
Window: reflective for high frequencies, absorber for low frequencies

FURNITURE

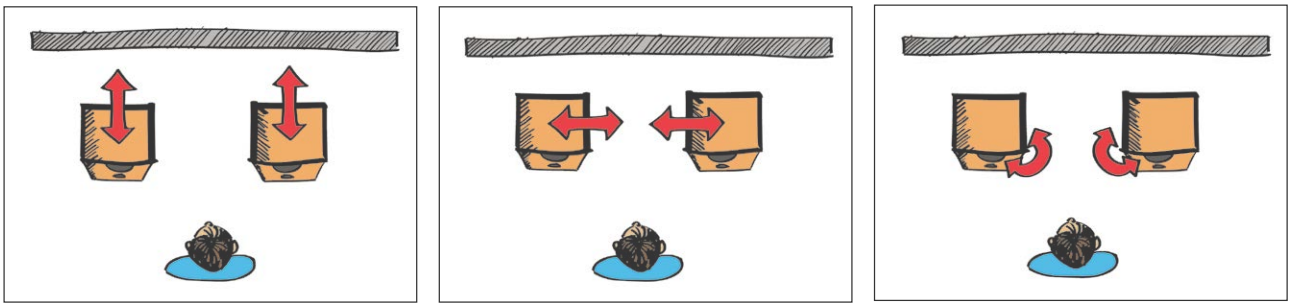
Cupboards: bass absorber
Shelves: diffusers
Seating furniture: treble absorber, depending on the degree of porosity
Tables: reflectors
Beds: treble absorber
Fabrics (wool etc.): treble absorber

OTHER

Curtains: treble absorber
Plants: treble absorber and diffusers
Tapestry: middle and treble absorber, depending on wall distance



If it sounds unsatisfactory, it might be worthwhile to rotate the setup 90 degrees or even try a diagonal variation.



The speaker placement begins with the search for the optimal distance to the rear wall in order to avoid bass exaggerations. Homogeneity is achieved by the distance between the speakers, while depth and focus change when the speakers are angled.

passages and the saxophone sounds more fluid in "Take Five", deep instruments are less convincing now.

After all, our experiment to turn the listening situation by 90 degrees has shown how much one can change one's own room acoustics with comparably little effort, and from the first initial situation in an empty room to step 3 – good speaker placement combined with a homely ambience – the situation has improved significantly. This underlines once again that sparsely decorated rooms are generally detrimental to good acoustics, while carpets, bookshelves, sofas, etc. not only provide a pleasant living atmosphere, but also greater hi-fi enjoyment. Only very "plush" living rooms would be bad due to excessive damping.

Nevertheless, we are still a long way from achieving perfect acoustics – especially in the bass range. Since furniture is only of limited use here, it is worth experiment with professional room acoustic elements for this matter. ■