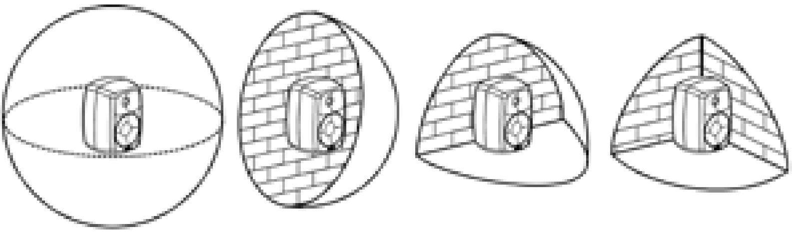
Loudspeakers in rooms

This article focuses on the complex interaction that will determine the quality of the audio reproduction around the listening area. CHRISTOPHE ANET from Walters-Storyk Design Group concludes our acoustics primer series.



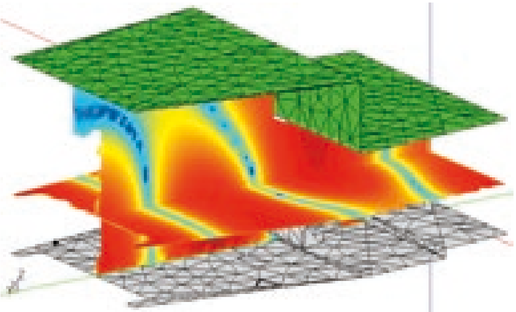
SOLID ANGLE 4	SOLID ANGLE 2	SOLID ANGLE	SOLID ANGLE /2
Free space	Half space	Quarter space	1/8th space
Free Standing	Flush Mounted	In a corner	In an apex
	Or next to a wall	(limited by two walls)	(corner limited by three walls)
Theoretical amplitude gain at low frequencies (below 200Hz):			
0 dB	+6 dB	+12 dB	+18 dB

Limited radiation space size affects loudspeaker bass boost. (Courtesy of Genelec)

Loudspeakers and subwoofers radiate very long wavelengths at low frequencies and produce a certain volume flow. At low frequencies this volume flow spreads into all directions. If we limit the space by walls while keeping the sound output power identical, the energy density (also called intensity) in the limited radiation space increases. So, every halving of the radiation space doubles the sound pressure level.

At high frequencies the loudspeaker no longer radiates in all directions. As the frequency goes up and the wavelength becomes shorter the loudspeaker radiation becomes increasingly more directional. Hence, placing a loudspeaker on the wall does not increase the high frequency sound level but at the same time low frequencies are boosted and the frequency response of the loudspeaker is no longer flat. The loudspeaker sounds boomy or bass-heavy. Thus, it is important to correct this phenomena occurring in the loudspeaker or subwoofer response to maintain a flat and balanced frequency response.

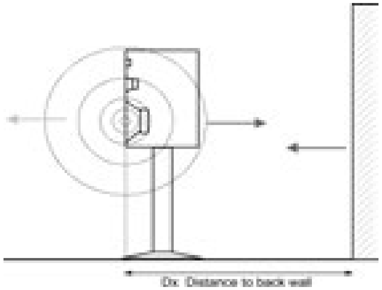
To predict the listening room behaviour at low frequencies, complex 3D simulation of the energy flow and the related pressure zones are calculated. Such models allow for tailoring room dimensions and shape as well as to define correct placement of loudspeakers and listening positions.



Acoustic Boundary Element Calculator (ABEC) model — low frequency analysis of a listening room. The red areas represent high pressure zones while blue areas indicate low pressure zones.

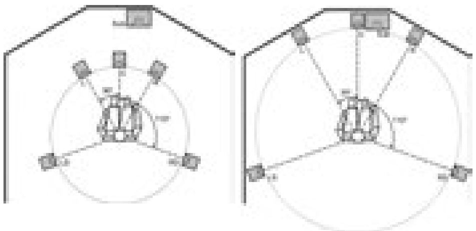
Boundary interference from the Wall behind Loudspeakers — Two signals with the same level but in anti-phase (180 degrees out of phase) can cancel each other out, resulting in silence. If the loudspeaker is placed a quarter sound wavelength away from a sound reflecting wall the wave reflected off the wall arrives back at the loudspeaker drivers in anti-phase. This cancels totally or partially the signal radiated by the loudspeaker at that particular frequency. How complete the cancellation is depends greatly on the ability of the wall to reflect sound in a specific frequency range. The sound level dips down at the frequencies where the reflected sound is in anti-phase. The depth and width of a cancellation dip varies but in most cases such dips are audible.

No loudspeaker equalisation cures this problem; increasing the level of the loudspeaker at the dip frequency also boosts the reflection and thus their sum remains low and the dip is not removed. The most efficient solution to avoid such cancellations is to flush mount the loudspeakers in a hard wall. This places the loudspeaker in an 'infinite baffle' and can totally eliminate the dipping phenomena as no reflections are present.



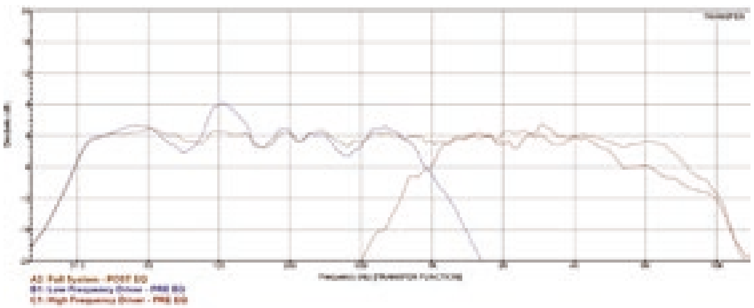
Wall behind the loudspeaker cancellation phenomenon. Distance to wall = ¼ wavelength. (Courtesy of Genelec)

Interaction between walls and freestanding loudspeakers — Using a subwoofer with a crossover filter (typically at 85Hz) between satellite loudspeakers and the subwoofer can be very useful. The (high-passed) satellite loudspeakers do not reproduce low frequencies. They can now be placed at the walls more freely at distances where low frequency notching does not occur in their pass-bands. The 'acceptable' distance extends now out to 1.1m. The loudspeakers can also be placed further away (1.1-2 m) without seriously compromising the sound quality.



ITU-R BS.775-1 loudspeaker placement with satellite speakers placed at least 1.1m from the wall and placed against a hard wall (Hemispherical loading). (Courtesy of Genelec).

Subwoofer placement in a room — One common location for the subwoofer is in the front centre of the room, equidistant from the sidewalls. This position is often a compromise on the acoustical performance. In the case of small rooms with parallel side walls, the subwoofer sits in the first pressure minimum of the lateral standing wave. The frequency response of a subwoofer in this location will most likely display serious irregularities.



In-situ frequency response measurements before and after calibration.

A better position for the subwoofer(s) is on the floor close to the front wall and slightly offset from the middle axis of the listening room (avoiding then the first pressure minimum), or in a corner close to the front and side walls. The latter position maximises the subwoofer efficiency due to corner loading but may also excite strongly the axial modes in the room. Both solutions eliminate the most likely sources of cancellation dips in the subwoofer response. Another alternative is to use multiple subwoofers to achieve a more even modal excitation of the listening room. However, the complexity of the low frequency radiation increases with the number of subwoofers used.

Remember that the adjustments of gain and frequency response of the subwoofer are necessary during the final in-situ calibration. The acoustical loading must be compensated for. Crossover phase adjustment is also important to achieve and maintain flat frequency response across the crossover region.

Vertical loudspeaker placement — Although the vertical positioning of loudspeakers is less critical than the horizontal one, inadequate placement will affect the overall sound quality. In a stereo setup, it is essential that both loudspeakers and acoustical axis are positioned at the same height. In a multichannel system, ideally, the three front loudspeakers should be positioned having their acoustical axis at the same height. It should be noted that the precise localisation of a loudspeaker's acoustical axis is defined by the manufacturer in its technical documentation.

While the brain has a high capability to localise information on the horizontal plane, in the vertical plane the precision is (zenith angle) about 3 degrees above ear level horizon and 3 to 10 degrees below ear level horizon (azimuth angle). Because of this behaviour of the ear/brain, human vertical localisation tolerance is about 7 degrees. This allows two sources to be positioned at slightly different heights without the brain being disturbed by such height difference.

This useful human hearing limitation can be positively exploited — a centre channel loudspeaker can easily be placed above video screens or TV monitors. Then, you have to make sure that this centre loudspeaker does not suffer from a first order ceiling or console reflection.

Early reflections and sound colouration — Early reflections created by tables, racks, computer screens, etc. can colour the sound if the level of the early reflection is close to the level of the direct sound coming from the loudspeakers. The early reflections can also smear the coherence of sound images and compromise the localisation of sound sources in the space between loudspeakers.

Symmetrical positioning of the equipment is essential. Nevertheless, even with symmetry, reflections will remain and everything possible should be done to remove reflective surfaces between the loudspeakers and the listening position. To improve the situation loudspeakers can be placed slightly above the typical listening height and tilted down towards the listener. Finally, it should also be remembered that the smaller physically the loudspeaker the less directional it is and the more influenced it will be by its surroundings.

Most loudspeakers are built to have a flat response in anechoic conditions, once they are placed in a listening room their response changes because of room boundary loading, reflections, reverberation time characteristics, etc. Proper placement and precise adjustment of the monitor's response are needed so that the loudspeaker-room interaction stays optimal.

This article concludes our mini-series on Acoustics Essentials. So now, having made the effort to get to this point — understanding the basic principles, understanding sound on surfaces, understanding sound in rooms, understanding room-loudspeaker interaction — we are now prepared for the actual realisation of our dream facility.

Contact

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