Monitor placement in small rooms

The increasing use of small rooms as audio production environments needs careful consideration of the acoustic behaviour as well as correct loudspeaker placement. Genelec's CHRISTOPHE ANET outlines the impacts of using a small room (a typical 3m x 4m) and the challenges of setting up a 5.1 monitoring system.

Every room (with the exception of a perfect anechoic chamber) has a set of resonant frequencies. These frequencies and how much they are boosted are defined by the room geometry and the surface materials. In rectangular rooms, as well as most other rooms, the mode density increases rapidly with increasing frequency. The colouration of sound caused by the modal resonance depends on the spacing of the modes in frequency and how much the modes are excited by loudspeakers. Only if the room dimensions are smaller than half the sound wavelength no mode can exist, and sound pressure in the room depends only on the loudspeaker output capability.

Frequencies below about 300Hz are the most critical as the density of modes is fairly small with wide spacing between the modes. This makes the modes audible because they do not overlap and absorbing the resonant energy is difficult at low frequencies. Also, large rooms have a higher mode density than small rooms. This favours using a larger space as long as the reverberation time of the space remains sufficiently low. The exact distribution of the modes also depends on the relative proportions of the room dimensions. The worst case is a cubical room. There the identical dimensions lead to a coincidence of the three axial sets of modes, and the mode resonances along the three axes of the room amplify each other. As a general rule, you should avoid precise integer ratios in room dimension proportions. We are already beginning to see that using small rooms involves some acoustical compromise.

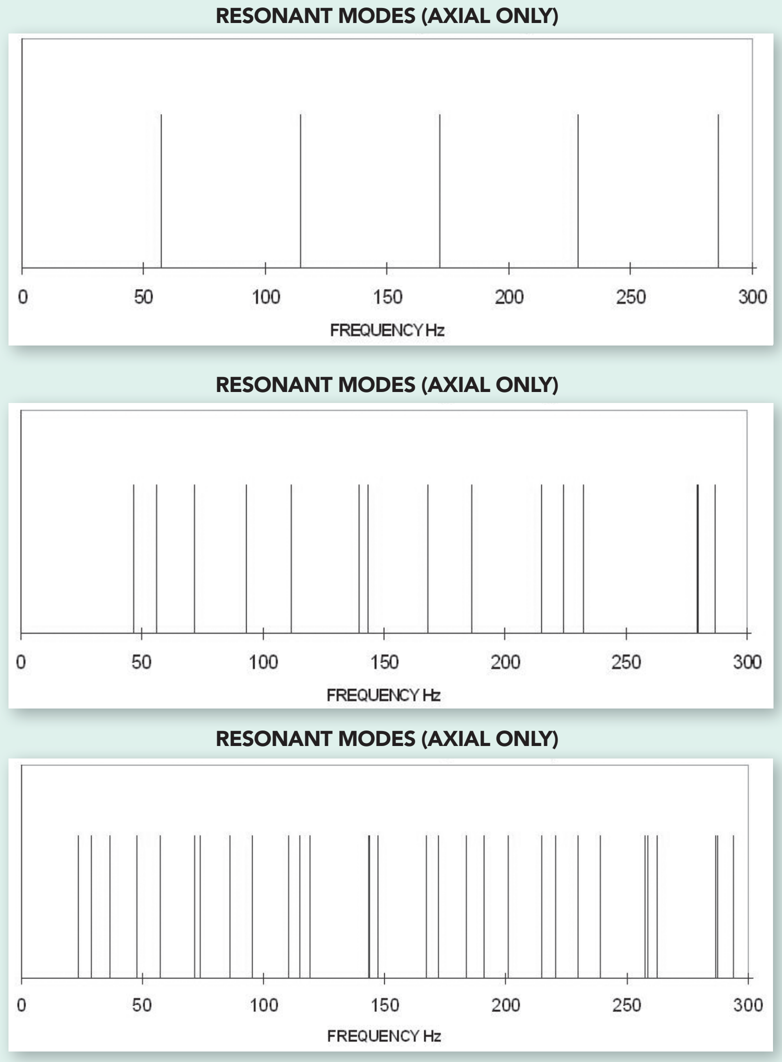
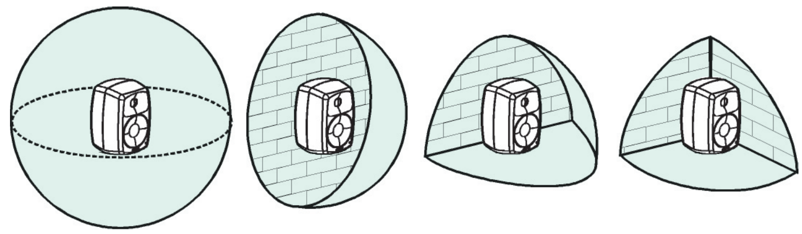


Fig. 1. Modal density can be increased by selecting the right proportions for the room dimensions. Top: 27m3 room with 1:1:1 ratio. Middle: 27m3 room with 1.54:1.28:1 ratio. Bottom: 200m3 room with 1.54:1.28:1 ratio.

RADIATION SPACE BOOSTS BASS LEVEL AT LOW FREQUENCIES — A loudspeaker or subwoofer produces a certain volume flow and at low frequencies this volume flow spreads in 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. Every halving of the radiation space doubles the sound pressure level.



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)			
0dB	+6dB	+12dB	+18dB

Fig. 2. Loudspeaker bass boost is influenced by the radiation space size.

At high frequencies the loudspeaker no longer radiates in all directions because the higher the frequencies the more directional they become. Placing the loudspeaker on the wall doesn't increase the high frequency sound level but low frequencies are boosted and the frequency response of the loudspeaker is no longer flat. The loudspeaker sounds boomy or bass-heavy. It is important to correct this problem in the loudspeaker or subwoofer response to keep the frequency response flat in the room.

THE WALL BEHIND THE LOUDSPEAKER CAN CAUSE CANCELLATIONS — 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 totally or partially cancels the signal radiated by the loudspeaker at that particular frequency. How complete the cancellation is depends on the distance of the wall and the ability of the wall to reflect sound. 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 their sum remains low. The dip is not removed.

The best cure to cancellations is to flush-mount the loudspeakers in a hard wall. This places the loudspeaker in an infinite baffle. This can totally eliminate the dipping phenomena as no reflections are present. In our small-room case we must place the loudspeaker very close to the walls in order to raise the frequencies where cancellations occur.

FREE STANDING LOUDSPEAKERS ARE AFFECTED BY NEARBY WALLS — Using a subwoofer with a crossover filter (typically at 85Hz) between the loudspeakers and the subwoofer can improve the monitoring system. The high-passed loudspeakers (sometimes called satellites) 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 be placed even further away (1.1m-2m) without seriously compromising the sound quality. The satellite loudspeakers should not be placed too far from the subwoofer (a maximum distance 2m). If the distances are larger the tonal balance between the various loudspeakers playing with the subwoofer may differ considerably due to differing excitation of the room modes. In practice freestanding loudspeakers

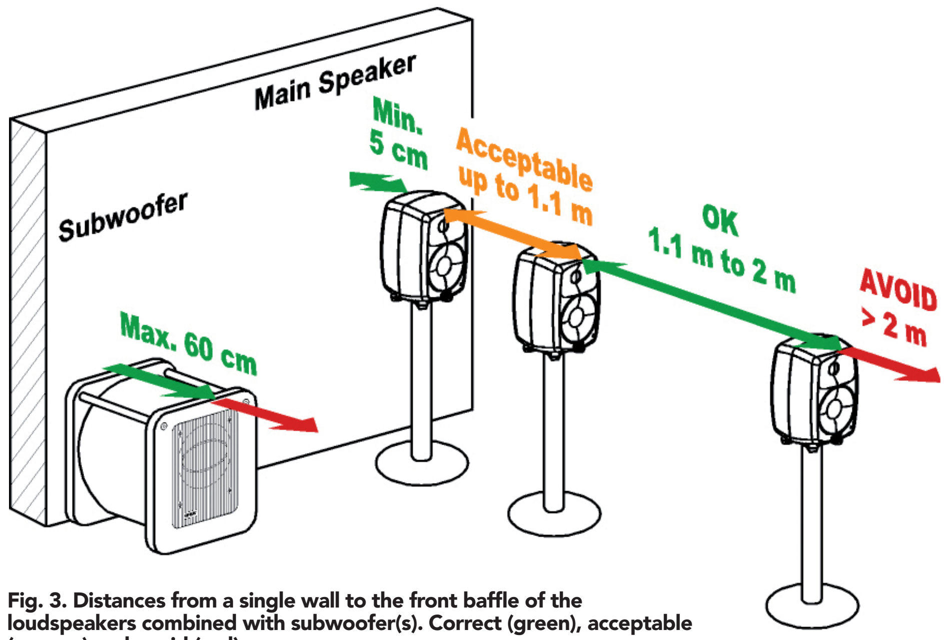


Fig. 3. Distances from a single wall to the front baffle of the loudspeakers combined with subwoofer(s). Correct (green), acceptable (orange) and avoid (red).

always suffer from some irregularities in their frequency responses, usually caused by cancellations.

One common location for the subwoofer is in the front middle of the room, equidistant from the sidewalls. This position is often problematic and compromises the acoustical performance. The subwoofer sits in the first pressure minimum of the lateral standing wave. The frequency response for a subwoofer in that location will most likely display serious irregularities.

The recommended positions for subwoofer(s) are on the floor close to the front wall (maximum distance from a wall is 60cm) and slightly offset from the middle of the room to avoid the first pressure minima position, 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.

Remember that the adjustments of gain (input sensitivity) and frequency response (Bass Roll-off) in a 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.

BASIC CHOICES FOR LOUDSPEAKER PLACEMENT AND ROOM SETUP — The majority of audible problems in monitoring quality are due to the effects of the room on the sound radiated by the loudspeakers and subwoofers. Proper placement of the loudspeakers and subwoofer in the room is critical. Let's return to our small room example.

First, the longest room dimension should be the axis for the sound system front-back orientation. This maximises the delay of the rear wall reflections at the mix position.

Symmetrical positioning of loudspeakers and all other equipment reflecting sound is essential. If we follow this rule the frequency responses of the loudspeakers working as stereo pairs will be similar. Even after this has been done, there will be some differences in reflections. Everything possible should be done to remove reflective surfaces in the vicinity of the acoustic path. Also, the smaller the loudspeaker is physically the less directional it is and the more the loudspeaker is influenced by its surroundings.

To provide proper loading for each loudspeaker as explained above place all loudspeakers at an equal distance from the listening position at the walls (ITU alignment circle). This implies placing loudspeakers against or very close to walls, as well as placing the subwoofer on the floor and against the front wall (you have a quarter space radiation then) or possibly in a front corner (1/8th space).

With such guidelines applied to our small room the monitoring setup circle radius (listening distance) becomes 1.38 m with a recommended listening area of 1.4m x 0.6m (hatched area). Note that the desk on the drawing is 1.2m wide and 0.6m deep.

PLACEMENT OF EQUIPMENT INFLUENCES SOUND QUALITY — The vertical positioning of the loudspeakers is also important, but less critical than the horizontal positioning. Ideally, the three front loudspeakers should be positioned at the same height. 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 the behaviour of the ear/brain, human vertical localisation tolerance is about 7 degrees.

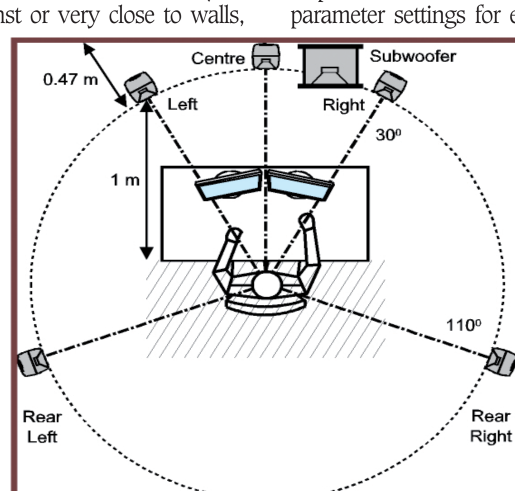


Fig. 4. 5.1 monitoring system in a 3m x 4m rectangular room without any acoustic treatment.

This allows two sources to be positioned at slightly different heights without the brain being disturbed by the height difference.

This useful human hearing limitation can be exploited when placing the often compromised centre channel loudspeaker. The centre loudspeaker should be placed above video screens or TV monitors. Ensure that the centre loudspeaker does not suffer from a first order ceiling reflection. If the ceiling is low some absorbing material should be placed over the ceiling surface near that centre loudspeaker.

Left and right loudspeakers should also be raised ideally to the same level as the centre loudspeaker to maintain a stable sound stage image. If this is done the loudspeakers should be tilted down towards the listening position.

Early reflections can colour the sound if the level of the early reflection is close to the level of the direct sound. Early reflections can also smear the coherence of sound images and compromise the localisation of sound sources in the space between loudspeakers. To avoid this all reflective surfaces between the loudspeakers and the listening position should be minimised.

Loudspeakers should be placed as far as possible from reflective surfaces. Increasing the reflecting surface distance moves the reflection-related problems to low frequencies and also improves imaging. In the presence of many reflecting surfaces (such as tables, computer screens, etc) loudspeakers can be placed slightly above the listening level and tilted down towards the listener.

HIGH FREQUENCY RESPONSE IS SENSITIVE TO LOUDSPEAKER ORIENTATION — High frequency information is of the utmost importance for the listener to evaluate subtle movements and variations in the audio stage. If room reflections are too high compared to the direct sound the imaging becomes poor. Loudspeakers should have well controlled directivity. It leads to a high direct-to-reflected sound level ratio and reduces the effects of nearby sound-reflecting boundaries. This helps the engineer to hear the programme material content and reduces the room effects. The purpose of the Genelec Directivity Control Waveguide (DCW) is to control the radiation angle of the tweeter and midrange drivers such that diffractions from the loudspeaker enclosure and room surfaces are minimised. Localisation, imaging, and flatness of the frequency response are improved irrespective of the loudspeaker location.

CALIBRATION IMPROVES QUALITY AND CONSISTENCY — To provide the best possible reproduction quality every monitoring system should be calibrated in its final installation (as already specified in the N12 Nordic Broadcast recommendation of the 1970s). Today DSP processing is integrated in monitoring loudspeakers. The most important benefit of this technology is the possibility for automated calibration of a loudspeaker system within a given room. Calibration tools like Genelec AutoCal, featured in GLM and GLM.SE, measure and determine the system response and calculate all the correct acoustical compensations and correction parameter settings for each and every loudspeaker and subwoofer. The automatic system determines acoustical settings to give a flat frequency response at the listening position (or over an area using spatial averaging) using notch and shelving filters available in each loudspeaker and subwoofer. It also aligns loudspeakers in time for an equal delay from all loudspeakers to the primary listening position, aligns output levels of loudspeakers and sets the subwoofer crossover phase. The entire calibration process takes less than five minutes for a full 5.1 system.

As more small rectangular rooms with strong modal resonances at low and midrange frequencies, low ceiling heights, and non-symmetrical equipment layouts are used as audio production rooms, the need for proper loudspeaker placement and consistent system calibration is more essential than ever. A well engineered monitoring system, containing DSP equalisation and supported by an automated equalisation method, can bring these difficult and challenging environments close to the quality of properly designed control rooms. In all cases correct loudspeakers and subwoofer placement is essential.