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*Original scientific paper*

# OPTIMAL DESIGN FOR AN ON-WALL MOUNTED LOUDSPEAKER

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A b s t r a c t: This paper describes the problem arising from mounting the loudspeaker on a wall, which results in an uneven frequency response. The problem arises from the destructive interference of the direct sound wave emitted by the loudspeaker and the reflected sound wave from the wall. Examples are given of two known solutions for commercial loudspeakers that made certain improvement in view of the mentioned problem, followed by a new proposal for a solution of the same problem.

**Key words:** loudspeaker; wall-mounted; on-wall

## ОПТИМАЛНА КОНСТРУКЦИЈА НА ЗВУЧНИК НАМЕНЕТ ЗА МОНТИРАЊЕ НА ЅИД

**А п с т р а к т:** Во овој труд е опишан проблемот што произлегува од монтирањето на кутијата на звучниот систем на ѕид, што се манифестира како нерамна амплитудно-фреквенциска карактеристика. Проблемот произлегува од деструктивната интерференција на директниот звучен бран емитиран од звучникот и од ѕидот рефлектираниот звучен бран. Дадени се примери на две познати решенија на комерцијални звучници што дале одредено подобрување на спомнатиот проблем, а во продолжение е прикажан и еден нов предлог за решение на проблемот.

**Клучни зборови:** зучник монтиран на ѕид

## INTRODUCTION

As a rule, loudspeakers are mounted on some distance from the wall behind them. But, because of lack of space, sometimes this is not possible, so loudspeakers have to be mounted directly on the wall, leaving at the most 10 cm to 30 cm distance from the front panel of the loudspeaker cabinet to the back wall, that is with most of the small to medium size loudspeakers.

Figure 1 shows measured frequency response of a small loudspeaker with a 13 cm mid-bass unit, mounted on a front panel with a width of 16 cm. The distance between the front surface of the front panel and the back surface of the back panel is 21 cm. The measured frequency response of the mid-bass is typical for loudspeaker units this small and its frequency range is up to 5 kHz, so that in order to cover the whole audio spectrum up to 20 kHz a tweeter that usually works above 2,5 kHz via appropriate crossover should be used.

When the loudspeaker from Figure 1 is mounted on wall with its front panel on a 21 cm distance from the wall, we get what is described on Figure 2.

We can see on Figure 2 that the difference between the paths of the reflected and the direct soundwave is L2 + L3, which results in partial cancellation of the soundwave at the measuring point (the microphone) in the vicinity of the frequency which is one half of the wave length: $2f = c/(L1 + L2)$, where $c$ is the speed of the sound in the air. The cancellation is shown on Figure 3 as a deep in measured frequency response in the vicinity of $f$ = 345 Hz, with the same loudspeaker as on Figure 1, mounted on the wall as on Figure 2.

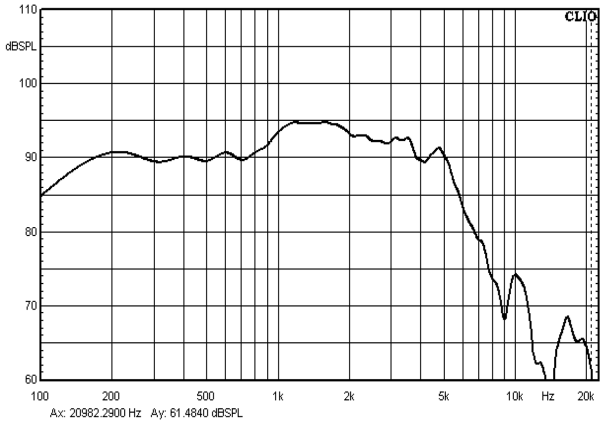


**Fig. 1.** Measured frequency response of a small loudspeaker, in free space, with no reflections

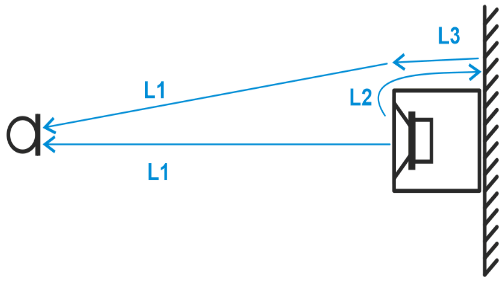


**Fig. 2.** Propagation of sound waves emitted from a loudspeaker mounted directly on a wall: direct sound wave (L1, below) and reflected sound wave (L2 + L3 + L1, above) from the wall

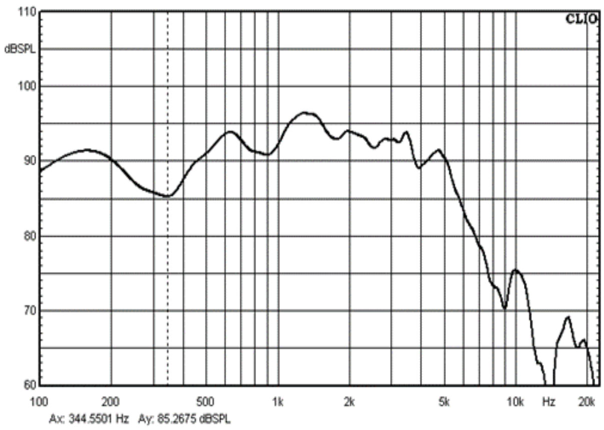


**Fig. 3.** Measured frequency response with loudspeaker mounted directly on wall, with the reflection from the back wall included

It should be emphasized that this cancellation appears only when measuring the direct sound signal and the one reflected from the wall, excluding any reflection from the rest of the walls in the room (as well as other bigger objects inside the room, e.g. the furniture). In real situation, when all the reflections in the room are included, the cancellation may not be that much pronounced, but it is still there. At lower frequencies (especially below 150 Hz) the difference between the paths of the direct and reflected sound is very small part of the wave length, so that the direct and the reflected sound are practically in phase, which results in amplifying of the lowest frequencies, in ideal situation up to 6 dB.

## REVIEW OF THE KNOWN SOLUTION

The problem with cancellation of the direct sound wave and the one reflected from the wall on which the loudspeaker is mounted has been researched in the literature [1], where stated are two solutions that lead to flatter frequency response (especially in the low frequency range), the first one being offered the same year (1974) as commercial product – Figure 4.

The first solution (from Figure 4.) is schematically presented on Figure 5.

**Fig. 4.** Commercial loudspeaker (Allison 6) with better frequency response – the mid-bass unit is on the top panel of the loudspeaker box, the tweeter is on the front panel, both protected with a grille fabric

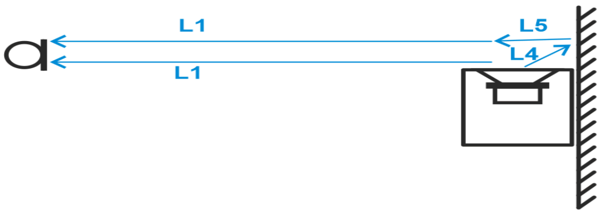


**Fig. 5.** Propagation of sound waves emitted from a loudspeaker mounted directly on wall, with mid-bass unit on the top panel of the loudspeaker box: direct soundwave (L1, below) and reflected soundwave (L4 + L5 + L1, above) from the wall

Figures 4 and 5 show that low frequency mid-bass unit is mounted as close to the wall as possible, which reduces the difference between the paths of the direct and the reflected sound wave L4 + L5, in relation to L2 + L3 from the previous example on Figure 2. It results in moving up of the frequency of cancellation, as seen on Figure 6.

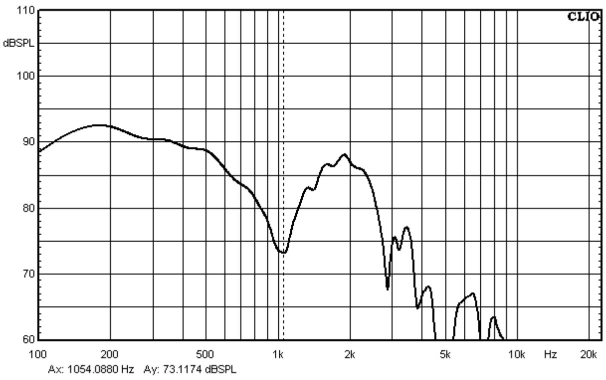


**Fig. 6.** Measured frequency response from a loudspeaker with a mid bass unit placed on the upper panel of the loudspeaker box very close to the wall, with frequency response only from the wall included

In reality, with all the sound reflection in the room included, this cancellation is not that deep, and not that intrusive for the ears as it happens toward higher frequencies.

Literature [1] suggests a second solution as well to achieving minimum possible difference between the paths of the direct sound wave and the one reflected from the wall – as shown on Figure 7.

Figure 7 shows that there is no reflected sound wave, because the loudspeaker unit, the panel of the loudspeaker enclosure (on which the unit is mounted) together with the wall surface form a rudiment kind of horn, through which only the direct sound wave passes. This means that there is no reflected sound wave to possibly interfere with the direct sound wave, thus no deep in the frequency response.

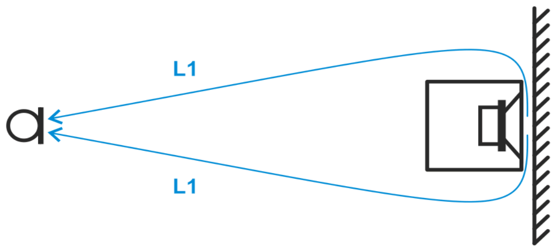


**Fig. 7.** Propagation of soundwaves emitted from loudspeaker mounted directly on a wall, very close to the wall (5 cm)

Figure 8 shows measured frequency response that really shows no presence of deeps, at the same time showing the effect of the horn – amplifying of part of the mid-range frequencies of around 800 Hz (which can be flatten by the crossover) as well as sudden drop of frequency response above 1200 Hz.

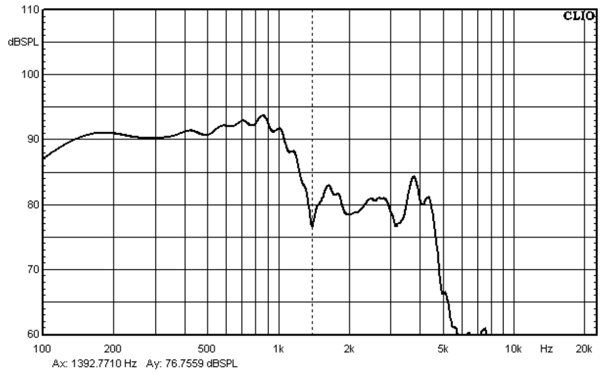


**Fig. 8.** Measured frequency response from a loudspeaker mounted directly toward the wall, at distance of 5 cm

The drop above 1200 Hz asks for a tweeter that can work starting from around (approximately) 1500 Hz. Crossover frequency this low can be withstand only by a high quality (expensive also) tweeter built in a horn.

There is a commercial loudspeaker of this kind on the market – Figure 9, with a crossover frequency of 1600 Hz.

**Fig. 9.** Commercial loudspeaker (JBL Control HST) with mid-bass unit positioned toward the wall at close distance, plus two tweeters in short horns, positioned outwards

## IMPROVED CONSTRUCTION

Figure 10 shows a suggestion for an improved construction, inspired by the construction on Figure 7.

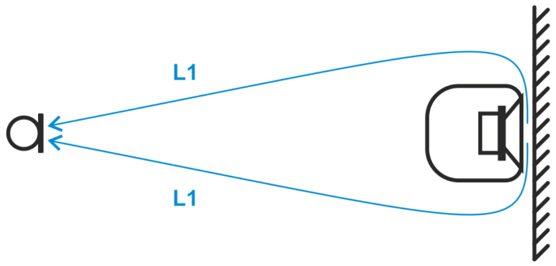


**Fig. 10.** Improved construction of the loudspeaker "box", with rounded edges of wide radius

The problem of the construction on Figure 7 and Figure 9 is the back panel of the box (even there is a chamfering of the left and the right vertical edge of the loudspeaker box from Figure 9) which results in uneven expansion of the horn comprising from the mid-bass unit, the panel on which it is mounted and the wall itself, so that the working range is shortened toward high frequency band. At the same time unwanted diffractions on the sharp edges of the loudspeaker box appear.Figure 11 shows measured frequency response of the prototype of the loudspeaker box, with the construction according Figure 10, only in this case the rounding of the surface is extreme – the loudspeaker "box" is actually a plastic sphere.

Figure 11 shows that the frequency response has been widen toward high frequency spectrum, thus the crossover frequency with the tweeter can be moved to comfortable 2500 Hz, easily withstood by a tweeter of an average quality. Small peaks in the vicinity of 1000 Hz and 2000 Hz can be flattened with the crossover or adequate phase plug in front of the membrane of mid-bass unit.

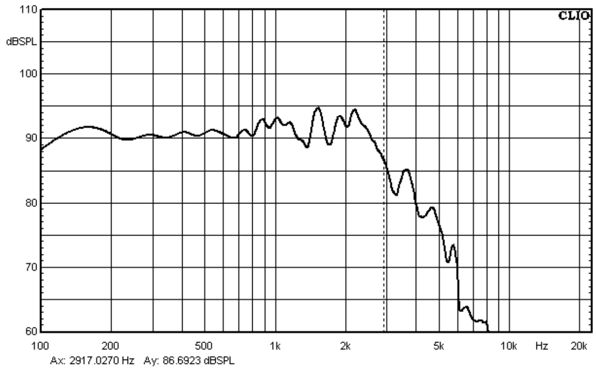


**Fig. 11.** Measured frequency response of improved construction

## CONCLUSION

This paper analyzes the problems with the uneven frequency response inherent to all on-wall loudspeakers, presents the two known solutions and gives a suggestion for a better (improved) constrution of the loudspeaker box with wider frequency range.

Further researches should lead toward a possibly better construction of the loudspeaker box, with an accent on the most appropriate shape of the back panel as well as check for even better results by adding a phase plug in front of the membrane of the mid-bass unit.

## REFERENCES

[1\] Roy, F. Allison (1974): The influence of room boundaries on loudspeaker power output, *Journal of AES*, Volume 22, Number 5, June.