Studies on the Structural Vibration and Cavity Resonance Behavior of Various Loudspeaker Enclosures and Baffles

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Structural vibrations of conventional and Super Silent Glass loudspeaker enclosures and baffles have been analyzed and compared to driver cone sound output using a highly linear accelerometer. The cavity resonance behavior has been estimated by examining a high resolution impedance plot. The impact of these phenomena on the sound generated by the driver is discussed by means of frequency response and cumulative spectral decay plots. Furthermore, it is shown that mounting a driver by its basket does not work as intended from the midrange and upwards in frequency.

1 Introduction

The reaction forces produced by the sound radiating drivers and the sound pressure (in particular inside an enclosure) excites mechanical vibrations in the loudspeaker enclosure as a whole, the walls of the enclosure, and the baffle of open baffle speakers. If these vibrations are strong enough in level they can have a detrimental effect on the linear and non-linear distortion properties of the loudspeaker system. These vibrations often have a high Q resonant nature that leads to "ringing". This can augment the negative effect of this phenomenon.

In order to study the level and properties of these vibrations, it was decided to acquire the impulse response of the various surface vibrations using a very linear accelerometer (Measurement Specialties ACH-01). The accelerometer was modified in order to more accurately detect vibration of very low amplitude and to enable a linear non-permanent attachment to the analyzed surfaces.

In order to asses the relative level of the enclosure or baffle vibration, the first measurement was performed on the cone of the driver. The shape of the cone makes it difficult to attach the accelerometer non-permanently. This sub optimal connection leads to some anomalies that can be seen as slight peaks and dips in the frequency response of the cone acceleration. Due to the better connection to the flat enclosure and baffle surfaces, these effects are not present in these accelerometer signals. All cone signals were normalized to roughly similar average levels.

The enclosure walls and baffles were measured at the maximum excursion area of the lowest mode. This area was chosen because it is commonly accepted that the detrimental effect of this phenomenon decreases with frequency. The lowest mode does for example not contain any reverse phase areas that might reduce the level of the radiated sound. The position of the measurement area was confirmed by a substantial number of measurements in various places and was usually found in the center of the surface, as expected. The levels of the surface signals were scaled conservatively with respect to the ratio of the cone and enclosure wall respectively baffle surface with a weighting of approximately 25%. The levels of these mechanical vibrations were not scaled to 100% because it is expected that the amplitude will decrease substantially with increasing distance from the maximum excursion area.

The true contribution of these vibrations to the sound generated by the driver cone is difficult to estimate exactly. It might well be a couple of dB lower or 10dB higher than shown in the graphs. From the impulse response, a graph showing the frequency response of the cone and the examined surfaces has been generated for every speaker system. Moreover, a cumulative spectral decay plot of the surface with the strongest signal is presented.

Cavity resonances of the internal air volume can lead to linear distortion due to leakage through the driver(s) in particular but even enclosure openings (e.g. vented boxes) and the enclosure walls. The existence of cavity resonances was checked by analyzing irregularities in a high resolution impedance plot. Placing large amounts of sound absorbing material inside the enclosure can more or less dampen these cavity resonances. It is known that the nonlinear friction losses of the dampening material can lead to a degradation of sound quality however. In vented enclosures, sound absorbing material even reduces the effectiveness of the working principle. Therefore, loudspeaker designers usually try to find an acceptable compromise.

2 22mm MDF Enclosure with Lacquer Finish

This compact closed bass enclosure (trapezoidal pyramid) is constructed using 22mm MDF and contains one 8” cone driver. It is filled with acoustic lamb wool and finished with several layers of lacquer. The classic “knuckle rap” test indicates a solidly built stiff enclosure.

The impedance plot (fig. 1) is very clean except for two irregularities at 280Hz and above 900Hz. As expected from the very well built and damped enclosure, these two irregularities are caused by the driver and cannot be related to cavity or structural resonances.

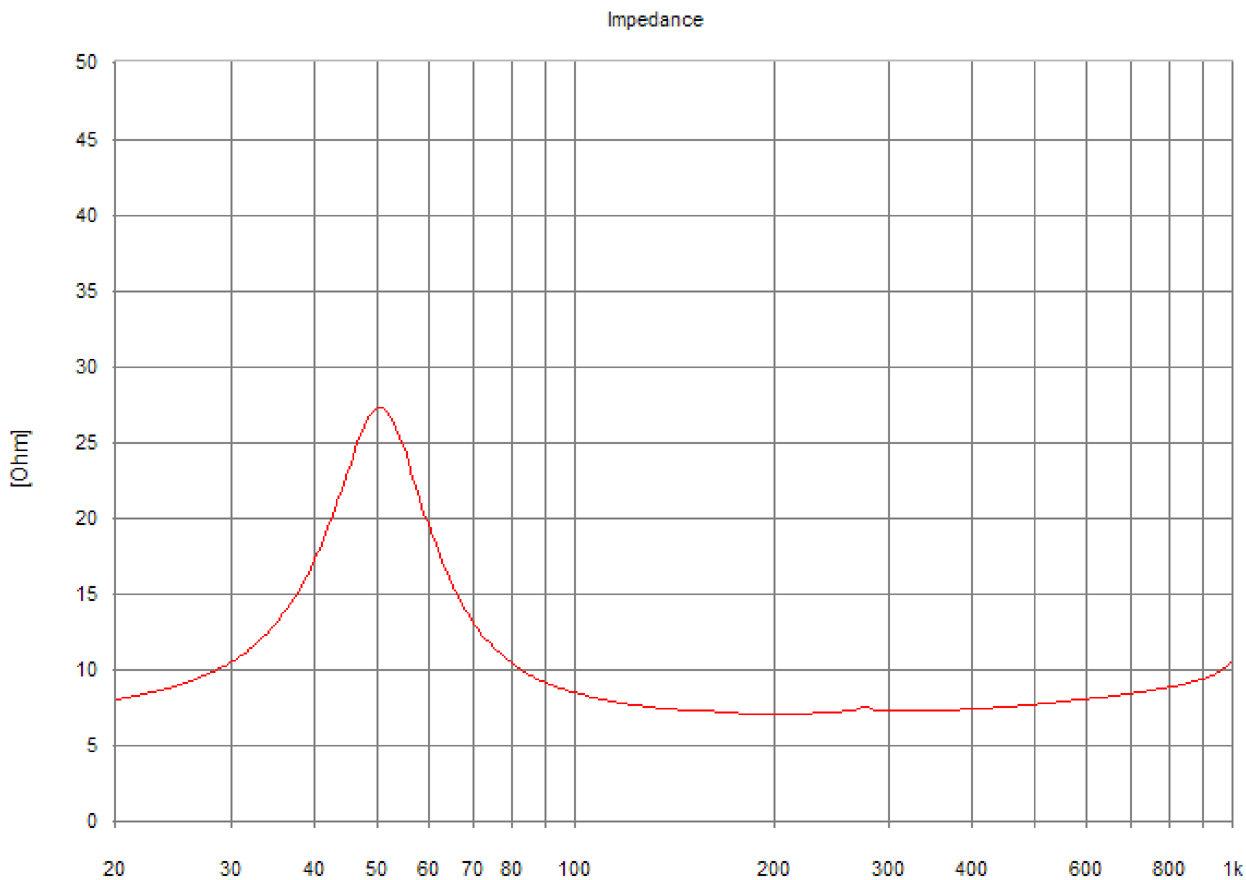

Fig. 1: Impedance plot of 8” driver mounted in enclosure

Through the accelerometer analysis, it was found that the front of the enclosure (where the 8” driver is mounted) produced the strongest vibrations. One significant feature shown in fig. 2 is that the enclosure actually vibrates over basically the entire frequency range. Due to the reaction forces generated by the bass driver, the enclosure moves in a pendular fashion throughout the low and mid bass. The irregularities below 60Hz are most probably caused by the interface of the enclosure to the floor. This behavior should be strongly affected by the type of “feet” (e.g. spikes, rubber, felt). The level is about 40dB down.

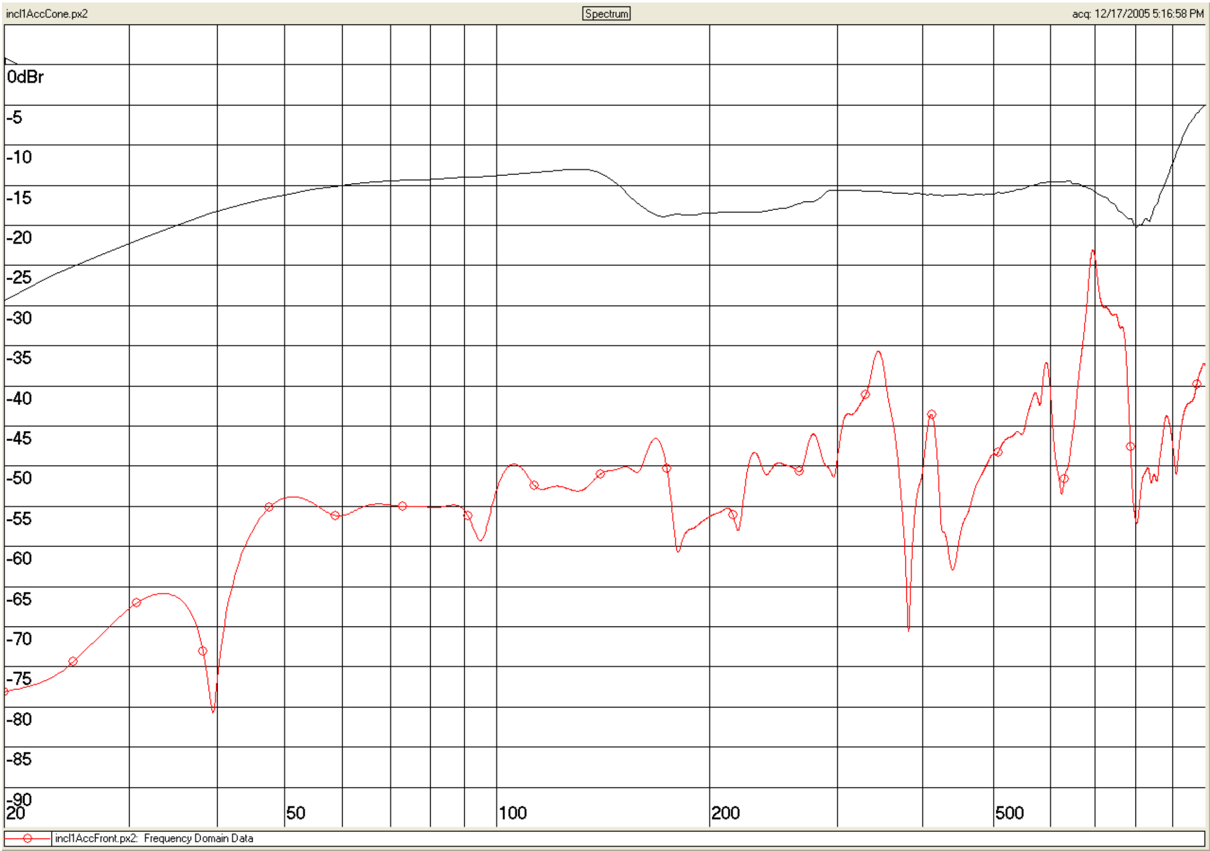

Fig. 2: Frequency response of the cone (black) and front baffle (red)

Higher up in frequency, strong enclosure resonances start to develop. Particularly, the peaks at 340Hz and 700Hz bear the potential for a degradation of the radiated sound (even more so if the radiation from the other surfaces would be added). I order to better estimate the effect a cumulative spectral decay plot is shown in fig. 3. It can be seen that these two modes are quite undamped and “ring” for a considerable time. This “ringing” will worsen the effect of these two modes on sound accuracy.

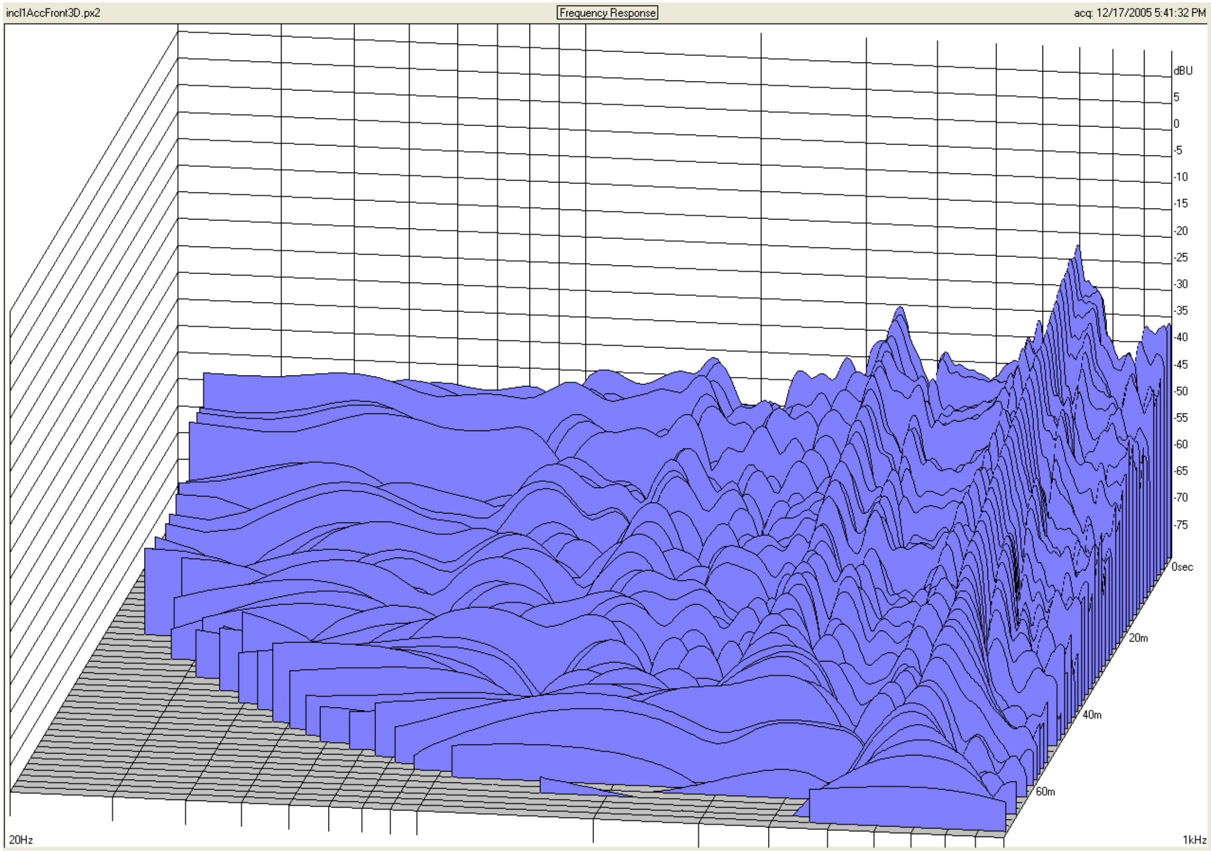

Fig. 3 CSD of front baffle

3 25mm MDF + 2x 1mm Veneer + 4mm Bitumen Sheets Enclosure

This compact closed bass enclosure (similar shape and size compared to the former enclosure) is constructed using 25mm MDF that is laminated with real wood veneer on both sides. It contains two 7" cone drivers in the front baffle. The cabinet walls have been lined with bitumen sheets to dampen wall resonances and the interior is filled with acoustic lamb wool. The "knuckle rap" test indicates a very solidly built, stiff and highly damped enclosure.

The impedance plot (fig. 4) is free of any irregularities as expected from the extremely well built and damped enclosure.

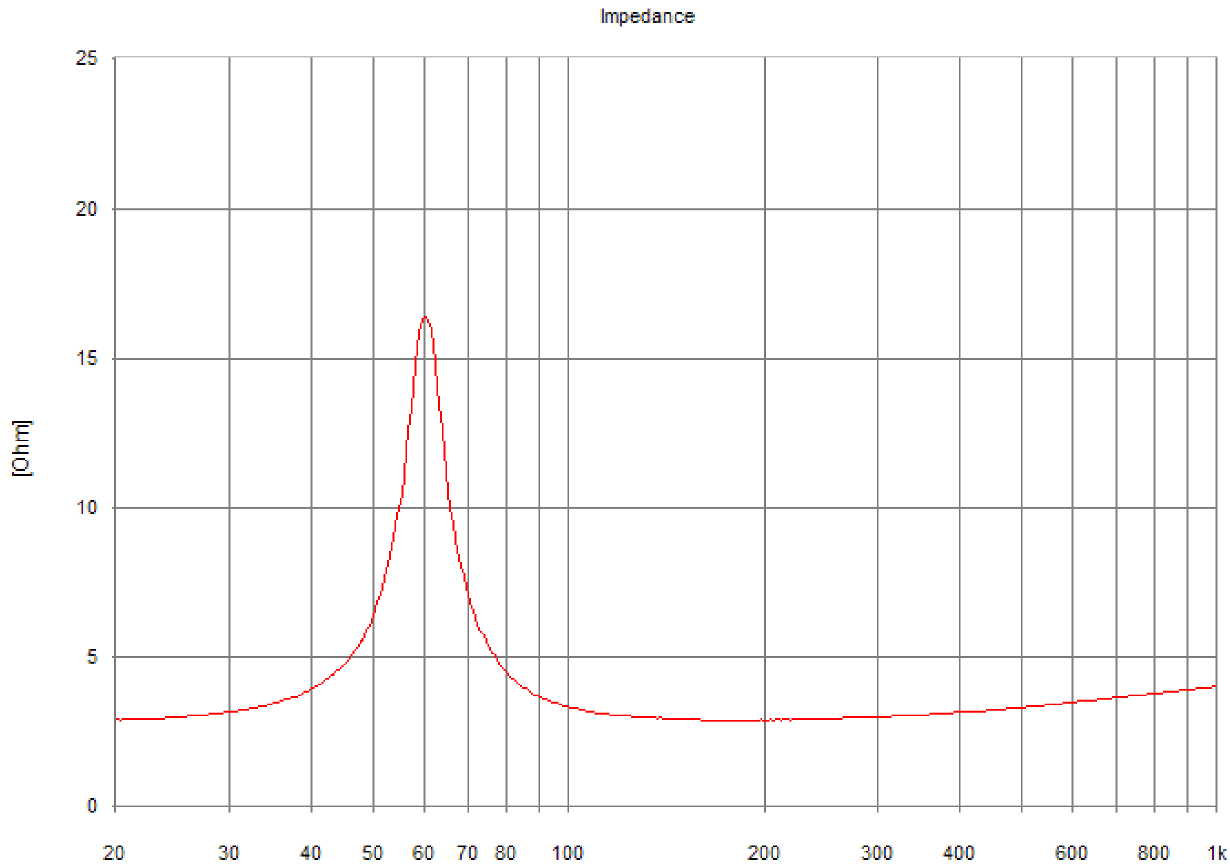

Fig. 4: Impedance plot of the two 7” drivers mounted in enclosure

As can be seen in fig. 5, the higher mass/surface ratio of the two 7” drivers, which put more energy into the enclosure, is obviously not compensated by the thicker veneered MDF and the bitumen sheets however (levels have been scaled to account for both drivers). Due to the different cabinet excitation of the two drivers (compared to the former enclosure), a mode at a low 130Hz has developed.

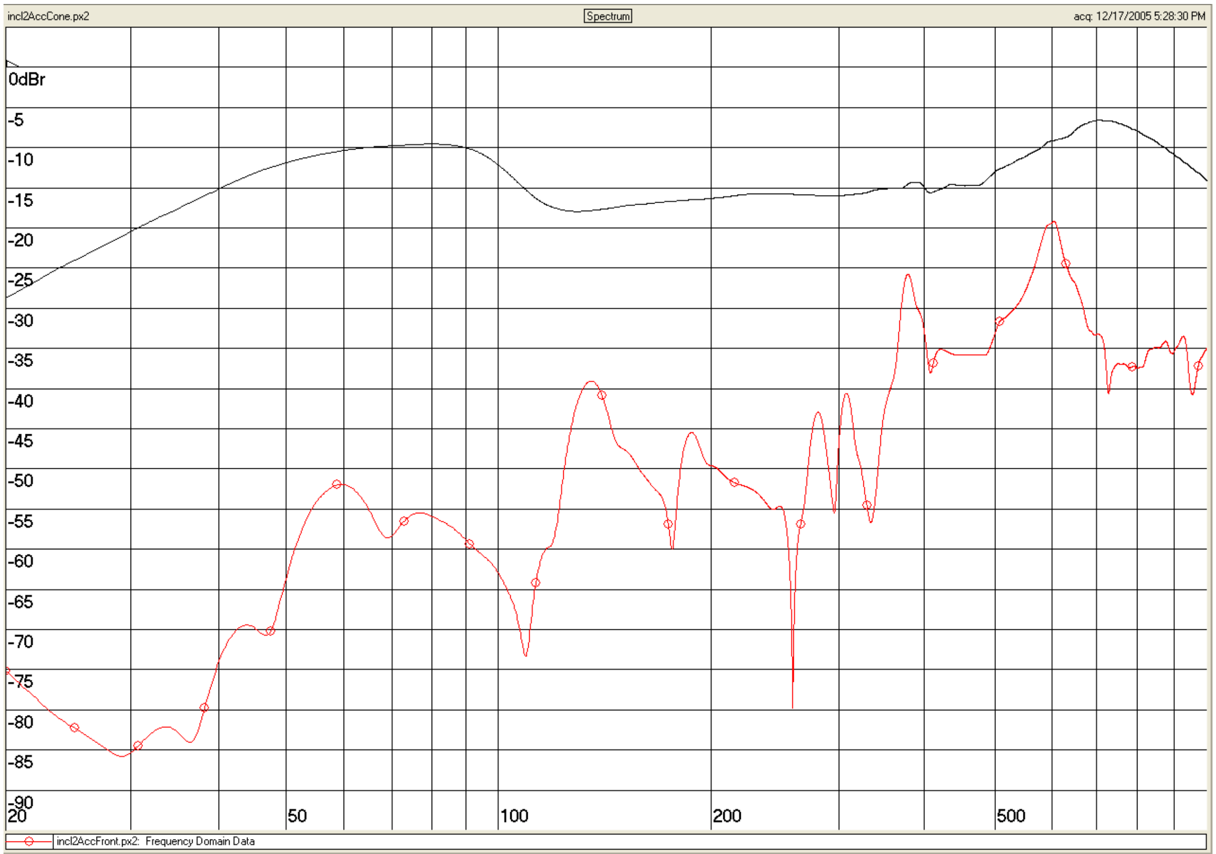

Fig. 5: Frequency response of the cone (black) and front baffle (red)

The cumulative spectral decay shown in fig. 6 reveals that this mode and the mode at 380Hz are rather undamped and ring for a long time. The high mode at 600Hz is, probably due to the bitumen sheets, comparably well damped.

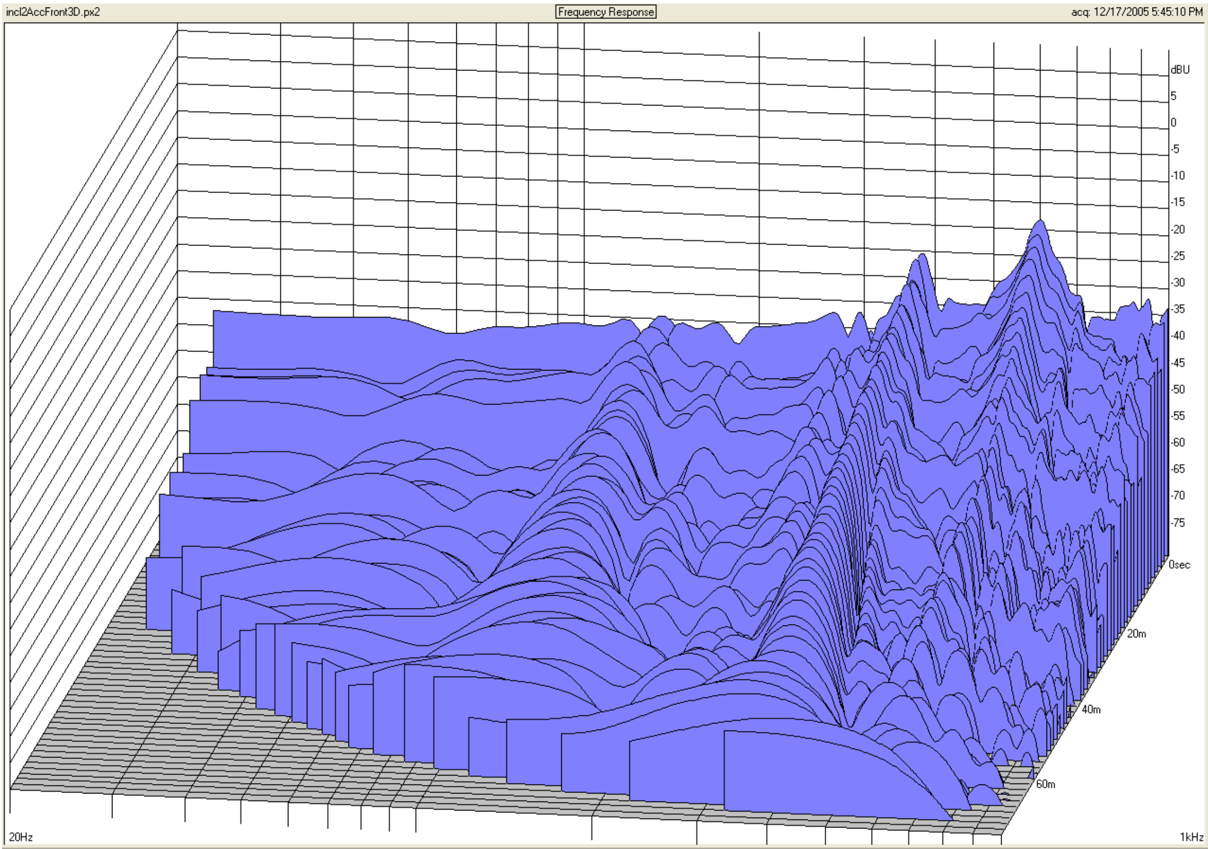

Fig. 6 CSD of front baffle

4 10mm Glass Enclosure Designed with SSG Technology

Due to the extremely low inner damping and many other issues, glass is usually not a suitable material for loudspeaker baffles or enclosures. The Super Silent Glass technology maintains the hardness and other advantageous properties of glass while it introduces very high damping. The closed enclosure is made of 10mm thick glass and does not contain any additional damping material inside. Theis is actually the original prototype for the Dreieck Sound XEOS Glass Speaker. The results shown are achieved by the way the glass is used and not due to the glass itself.

Due to SSG technology, the ringing of the glass has been eliminated and the impedance plot (fig. 7) is completely free from any irregularities. Moreover, it can be seen that the proprietary patent pending enclosure design and driver placement inherently avoids any cavity resonances throughout the intended passband despite the lack of any internal sound absorbing material.

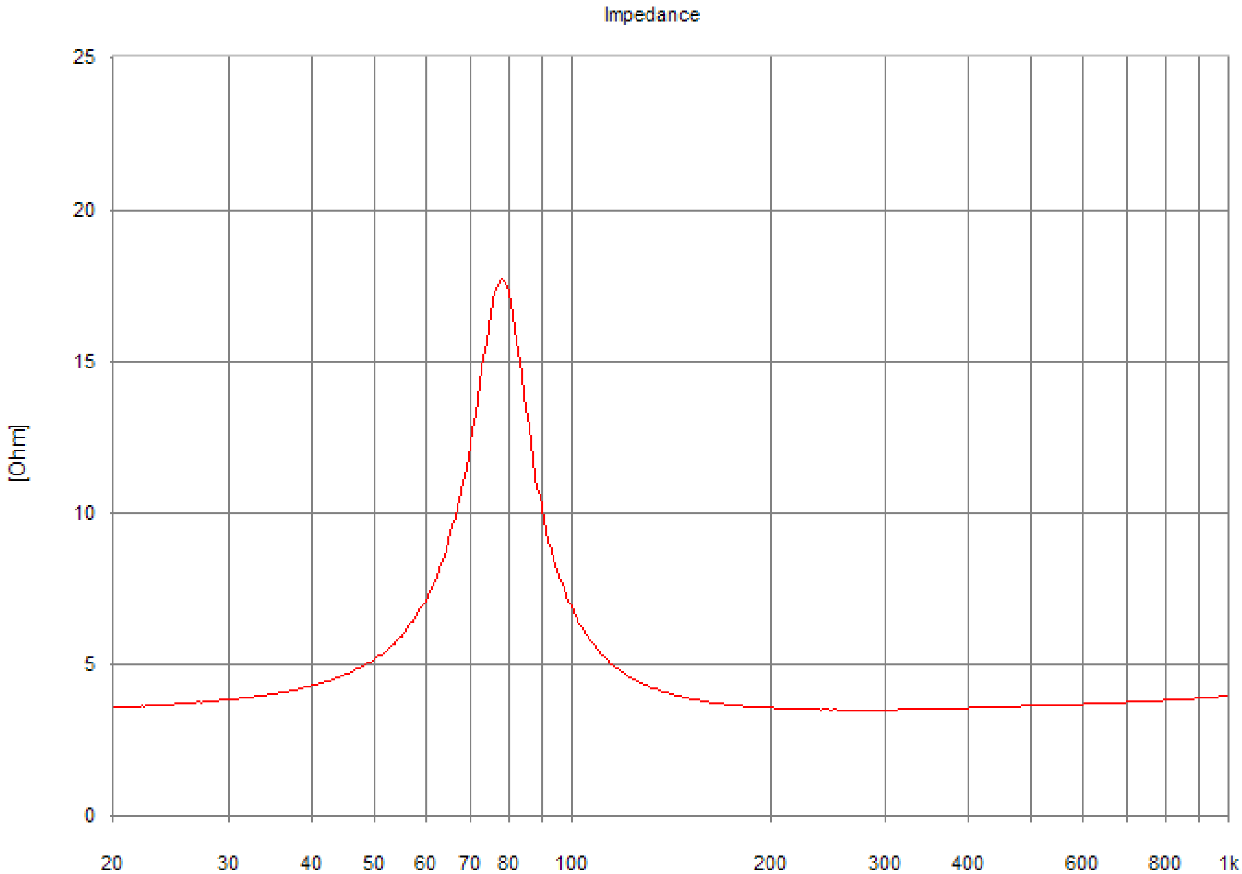

Fig. 7: Impedance plot of the two 7” drivers mounted in enclosure

The two 7” woofers are mounted on the two opposing enclosure sides. Due to the resulting reaction force cancellation, the general movement of the enclosure is reduced by about 20dB (fig. 8). The noise floor of the measurement setup prevents a determination of any side wall modes throughout the lower midrange. Above 600Hz a rise in the response can be made out, but the level is still very low.

The front and top surfaces have an approximately 10dB higher vibration level. However, it is surprisingly linear throughout the bass and lower midrange and no modes can be made out from the frequency response plot. These levels are still approximately 30dB lower than the MDF enclosures.

The glass speaker is designed to be placed on a glass stand that features a base with rolls. Both the stand and the roll base have levels that are buried in the noise of the measurement setup over most of the range. Due to the extremely low vibration level of the stand, the transfer of vibrations to the floor can be neglected and the influence of spikes, rubber feet, etc. has become obsolete. What is very surprising is that the level of the side walls of the enclosure over most of the range is comparable to that of the stand even though woofers are placed on these surfaces.

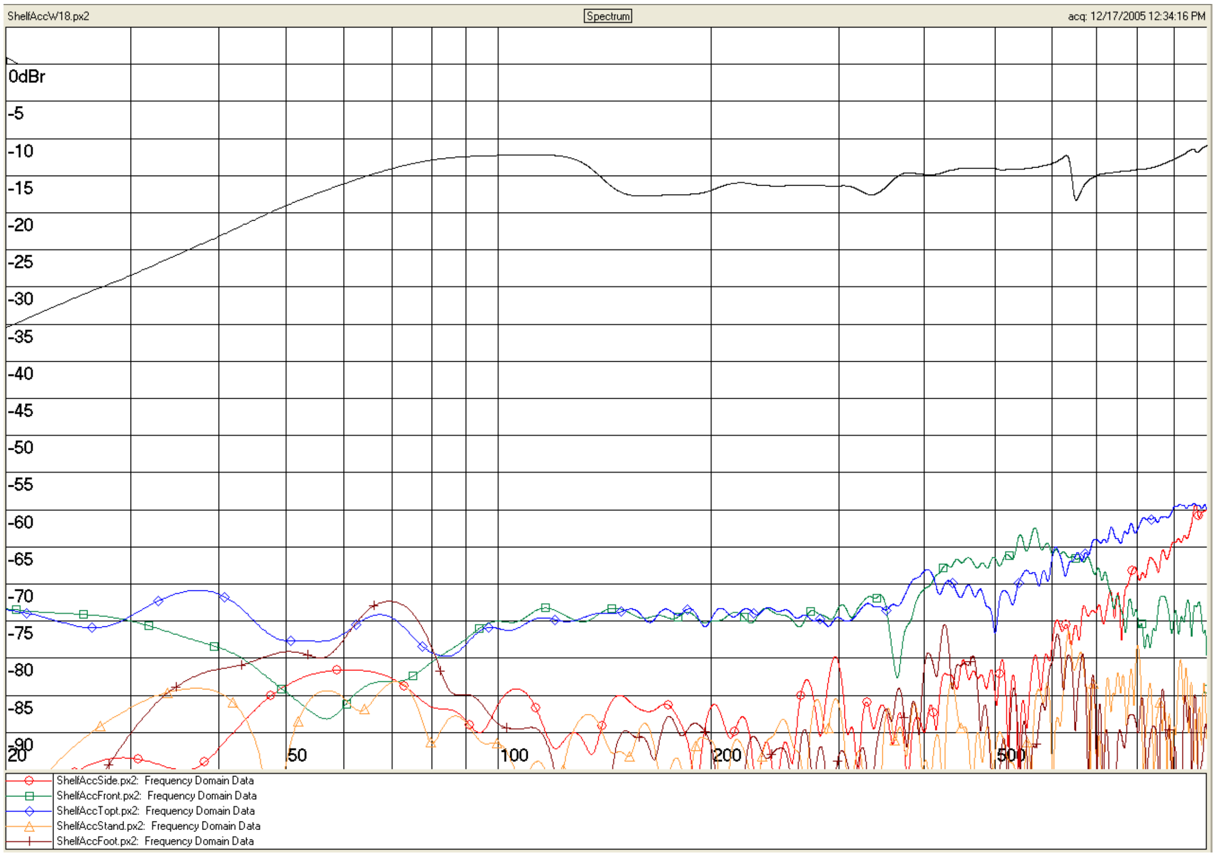

Fig. 8: Frequency response of the cone (black), side wall (red), front baffle (green), top wall (blue), stand (orange), and stand base (brown)

The cumulative spectral decay plot (fig. 9) shows a very even and fast decay except for a mode at 550Hz. The level is very low however.

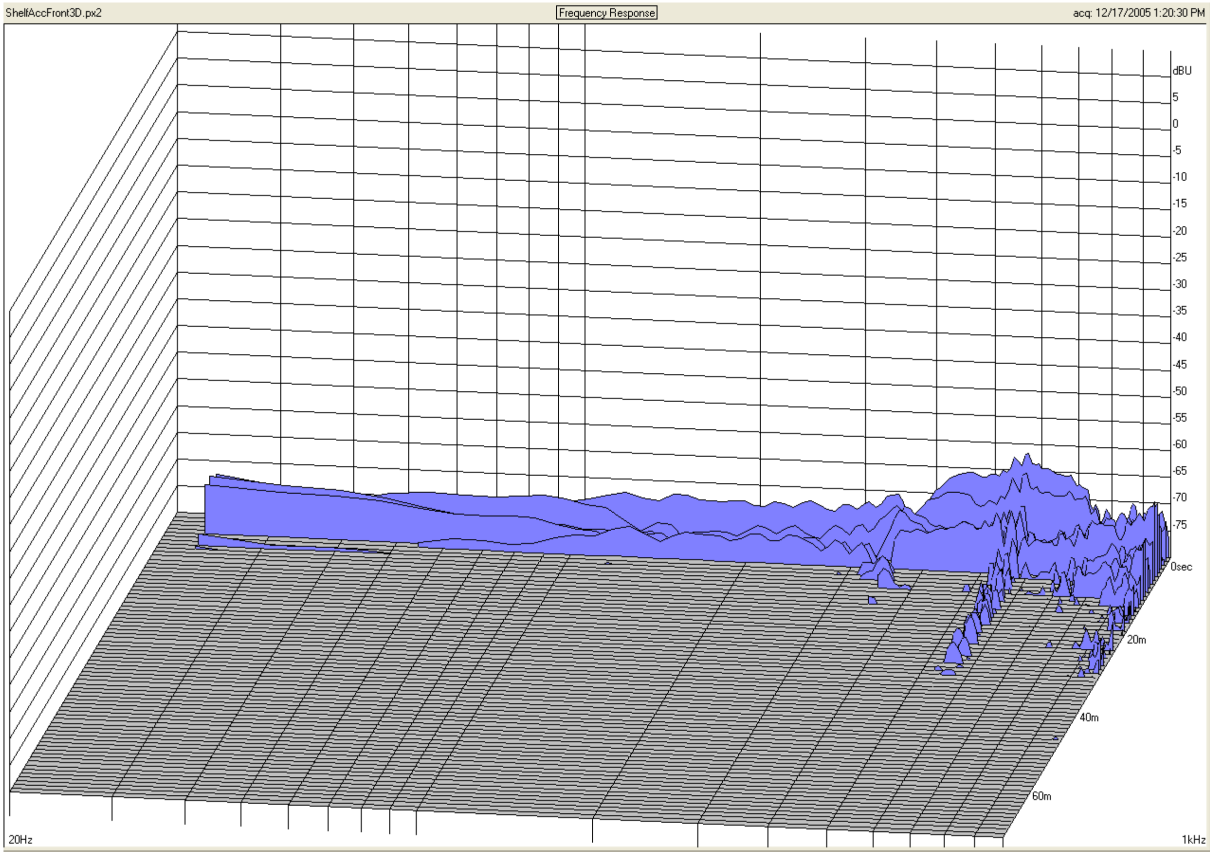

Fig. 9 CSD of front baffle

5 12" Wide Floor Standing Open Baffle made of 22mm Thick Birch with Two 7" Drivers

Due to the lack of internal pressure difference, open baffle speakers behave differently than typical enclosures. Vibrations are mostly induced by the reaction forces of the drivers and the structure is often inherently weaker and lighter compared to box speakers. The dipole roll off that would lead to an attenuation of the effect of the vibrations is usually compensated by the stronger reactions forces caused by the dipole equalization of the driver. In order to simplify a comparison with the box speakers, no dipole equalization was employed.

The analyzed open baffle speaker is constructed using 22mm birch and uses two 7" drivers. The low mass leads to a level that is 10dB higher than in the box speakers throughout the low and mid bass (fig. 10). Due to the weak structure, the first mode appears to occur at a low 100Hz. The midrange is characterized by many modes that are quite even in level. At these higher frequencies the effect of dipole cancellation of a 12" wide baffle can be neglected.

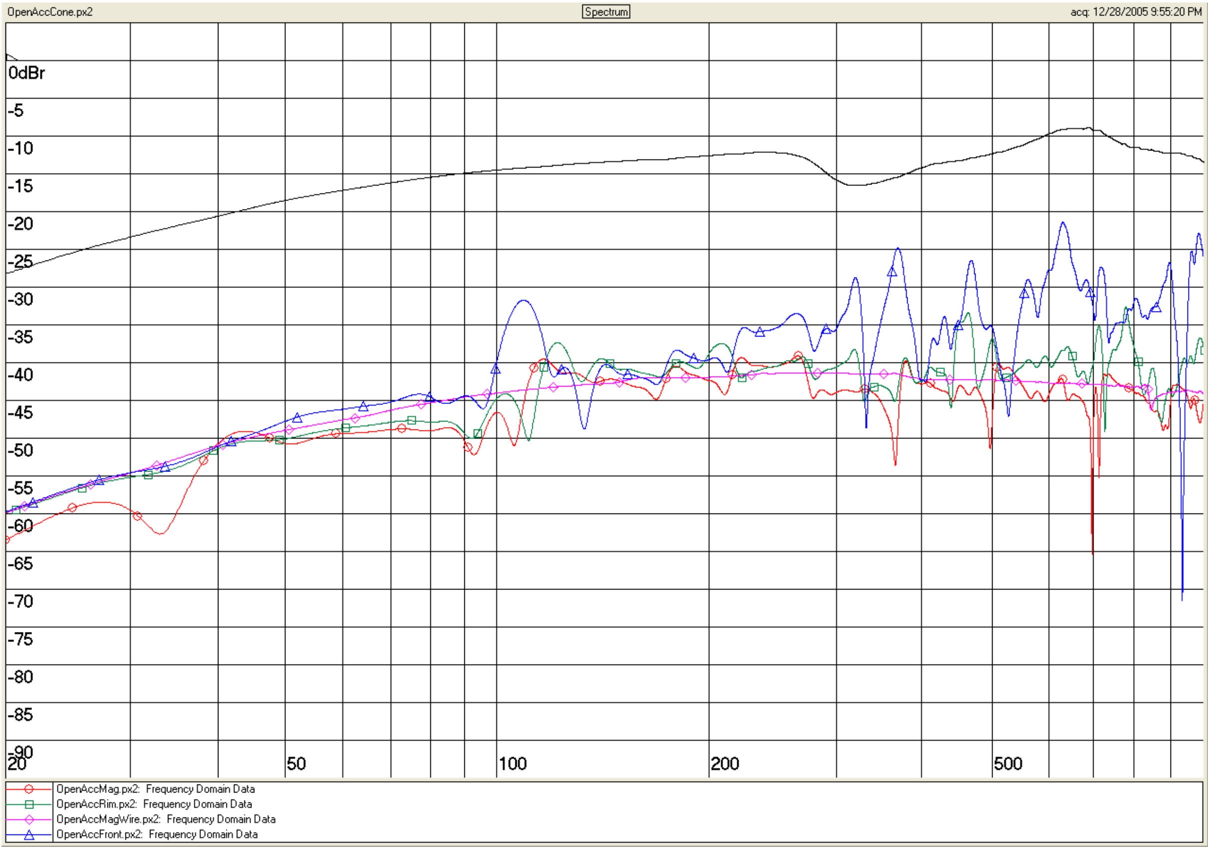

Fig. 10: Frequency response of the cone (black), baffle (blue), baffle mounted driver magnet (red), baffle mounted driver rim (green), unmounted driver magnet (wire suspended rim) (magenta)

The cumulative spectral decay (Fig. 11) reveals that the mode at 100Hz stores a significant amount of energy and “rings” for a long time. The higher modes stand out less compared to the few pronounced modes of box speakers. The level and delayed energy are rather high overall, however.

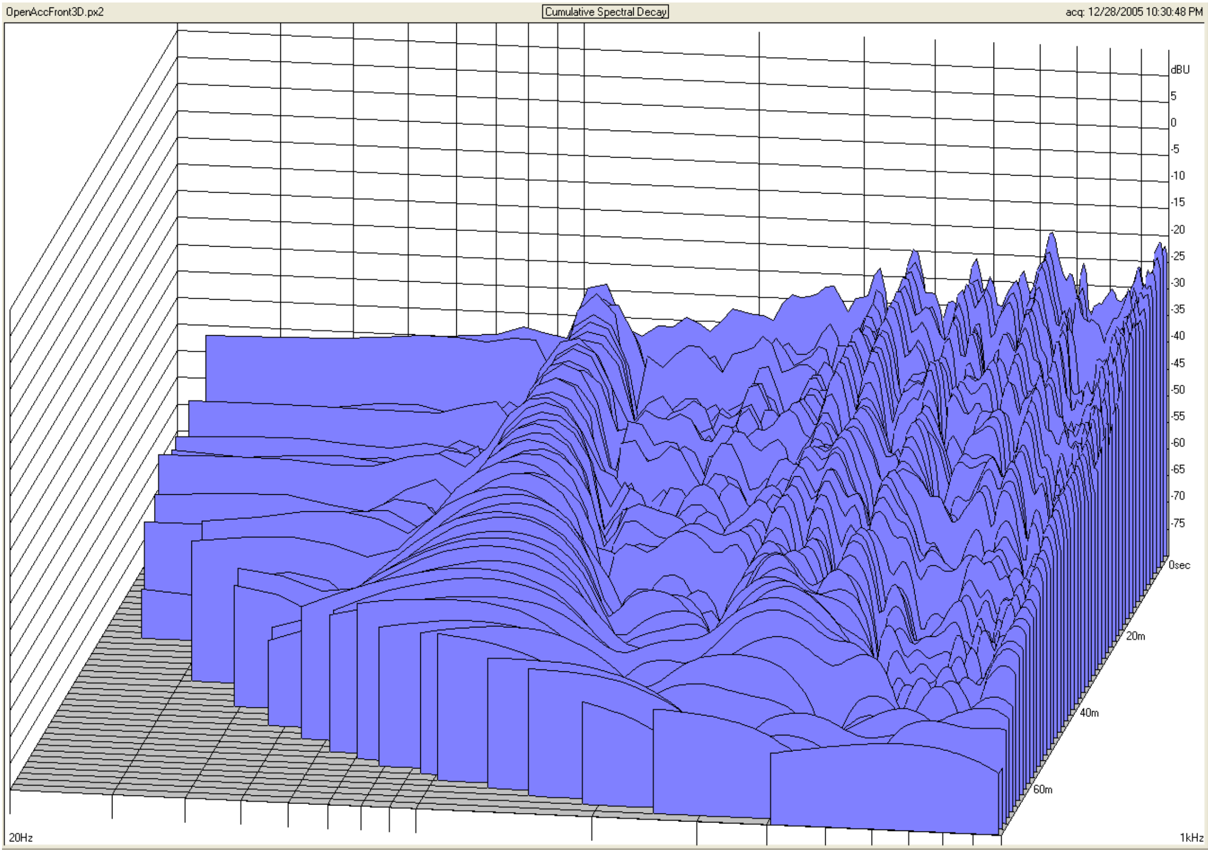

Fig. 11: CSD of baffle

As the magnet of the driver usually is easily accessible in an open baffle speaker, a measurement of the magnet vibrations was acquired and compared to the rim of the driver basket. It can be seen in figure 10 that there is no firm mechanical coupling of the magnet assembly to the bolted rim above a few hundred Hz and that narrow resonances are occurring in the basket structure. Finally, a measurement of the driver magnet was performed with the driver freely suspended in a wire (fig. 10 as well). Now, the response becomes very linear over the entire range and the level is hardly higher compared to the baffle mounted driver. It is obvious that the traditional mounting does not do any good throughout the midrange (and that the accelerometer setup is very linear indeed). It is simply not possible to actually fasten a driver with its basket from the lower midrange and upwards.

6 Open Baffle Designed Made of 36mm Layered Glass with SSG Technology

This is the original open baffle glass speaker prototype for the current the “Perfect8 The Force” speaker system. The 36mm thick glass leads to a significant increase in structure mass. The inherently structural weakness of a flat baffle would still allow panel resonances at relatively low frequencies and the basket would as usual not a allow a proper mounting of the driver throughout the midrange. Therefore, the eight 7” cone drivers are mounted to a perpendicular 250mm deep SSG baffle by their magnets.

The drivers and the perpendicular baffle are decoupled from the front baffle (a soft gasket seals the drivers’ basket rims to the front baffle). Figure 12 shows that this arrangement leads to a dramatic reduction of front baffle vibrations (around -50dB). The accelerometer signal barely reaches much above the noise floor of the measurement setup.

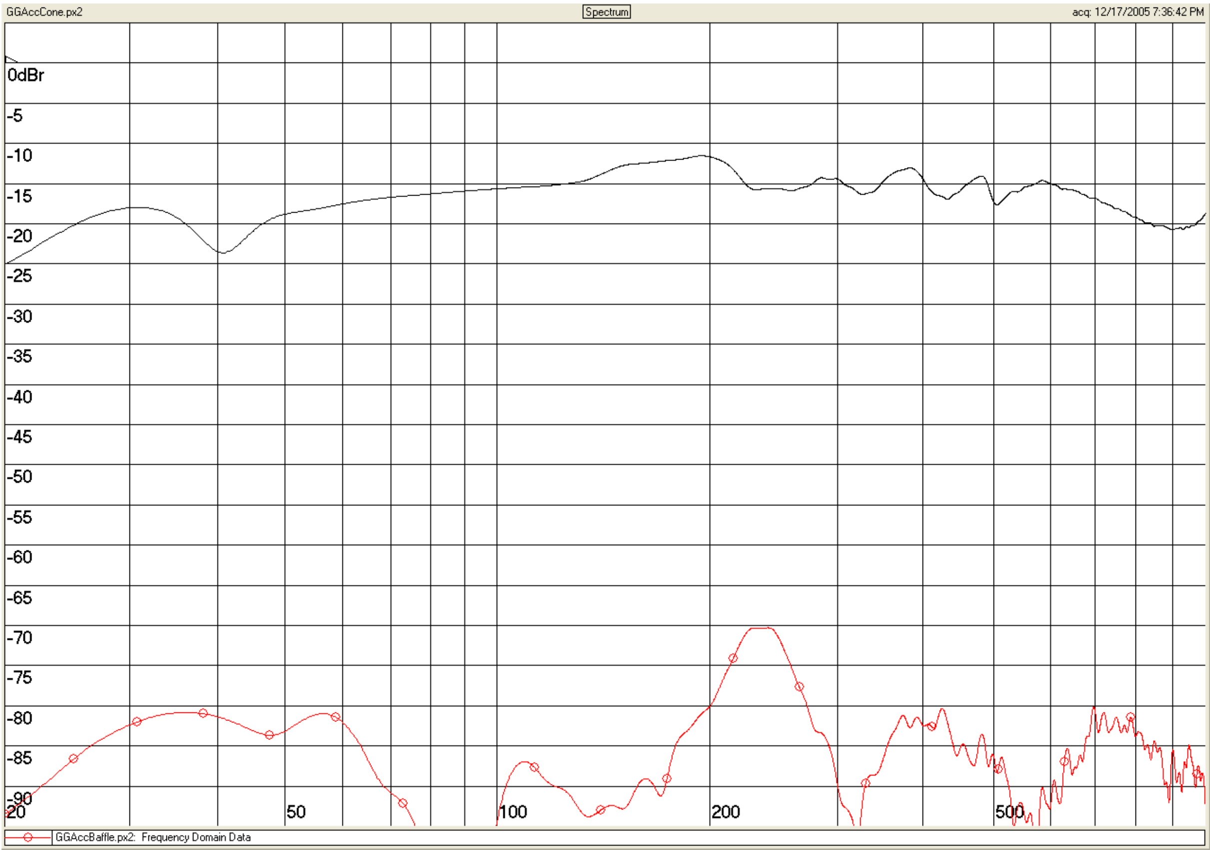

Fig. 12: Frequency response of the cone (black) and SSG front baffle (red)

The CSD (fig. 13) plot of the baffle shows only one very low mode that appears to be well damped.

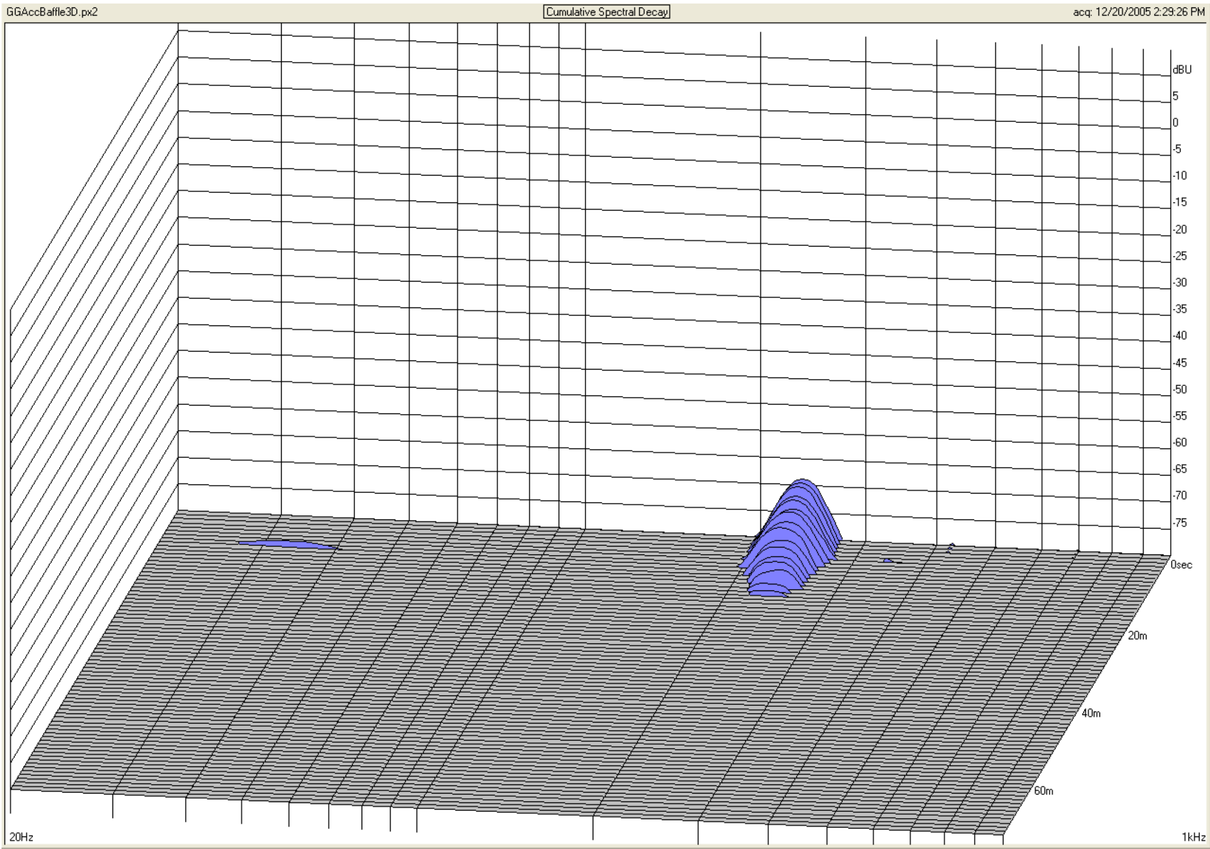

Fig. 13: CSD of SSG baffle

7 Discussion

These brief studies indicate that conventional enclosures that appear to be very stiff and damped still have the potential to negatively affect the accuracy of loudspeaker systems throughout the bass and midrange due to structural vibrations. Conventional open baffle speaker systems behave quite differently compared to box speakers. Even the baffle vibrations of these speakers bear the potential to degrade the sound of the driver itself.

The Super Silent Glass technology is able to reduce enclosure vibrations of speaker cabinets and baffle vibration of open baffle speakers to levels that should be more than well below any noticeable contribution to the sound of the drivers itself. The magnet mounting of the cone drivers eliminates the structural resonances of the basket that otherwise prevent an effective fastening of the drivers both when it comes to open baffle and box speaker systems.

Stuffing the entire interior of a closed box with sound absorbing material can reduce internal cavity resonances. Due to the nonlinear friction losses of the sound absorbing material, other areas of sound accuracy can be affected negatively. In vented boxes, sound absorbing material even reduces the effectiveness of the working principle. This dilemma is solved by the proprietary patented enclosure design and driver placement that inherently avoids any cavity resonances throughout the intended passband.