LS50 white paper

Introduction

The LS50 is a two-way loudspeaker system, inspired by the LS3/5A and conceived to celebrate the 50th anniversary of KEF. Like the LS3/5A, the LS50 has been developed with the extensive application of the latest engineering techniques, along with meticulous attention to detail. It uses KEF's latest 5” mid-range and 1” high-frequency driver units in a compact two-way system. Extensive listening tests were performed to ensure the right engineering choices were made to achieve the best possible balance. Both systems could be described as “Engineers loudspeakers”, where the design has been determined by engineering parameters and sonic performance, rather than marketing requirements.

Contents

Historical Context

The design of the LS3/5A is unusually well documented. The product brief was somewhat curious in that bass extension was only specified to 400Hz as the speakers was intended for use with male vocals in small studios, such as outside broadcast vans. The size of the enclosure was also an important part of the brief. In practice it was found that the KEF B110 bass-midrange driver could extend the response to below 100Hz, although, it could not be reflex loaded in such a small enclosure. The closed box is almost certainly a key aspect of its performance and is a feature shared by the Yamaha NS10. Somewhat ironically, the NS10 was originally a Hi-Fi design but became one of the most widely used desktop monitors in commercial studios, thus mirroring the LS3/5A's history. In [1] the BBC research department's design approach to the LS3/5A is discussed in some detail and in [2] some of the material measurements, and methods for assessing enclosure resonances, are introduced with many results. It is evident from these papers that a great deal of work and considerable expertise went into the enclosure design, making use of the BBC's extensive material knowledge and world leading methods for the measurement of acoustic output from the enclosure walls.

By today’s standards the LS3/5A is a somewhat unusual and costly design. The walls are fabricated from birch ply, selected for its combination of damping and stiffness, with a similar thickness of bituminous damping material applied to the centre of the faces. The rear mounted driver requires a removable baffle, which is fastened to beech fillets by numerous screws. Laser measurements of similar removable panels at KEF have shown that they have a significant impact on the vibrational behaviour of enclosures. Compared to a glued joint, the rigidity of a removable panel is somewhat reduced, the mechanical losses are increased and there is some degree of decoupling of the panel from the rest of the cabinet. Cabinet diffraction was, to an extent, also considered and reflections from the grille recess around the tweeter are absorbed with felt. The rear mounting of the bass driver results in a cylindrical cavity in front of the driver. Nevertheless, the balance seems successful in ameliorating any adverse effects of this. Relatively little attention was given to standing waves, with a simple lining of acoustic foam on the interior. The final balance, and various aspects of the enclosure design, were refined in an iterative process drawing on the BBC's expert listeners. The drivers had no modification other than the addition of a protective grille to the tweeter. It is also interesting to note that the BBC recognised a difference in sound quality between different capacitor types, but not between different manufacturers. It is a tribute to the designers that their work has survived the test of time to such a remarkable extent that the LS3/5A still has a place in the market after so many years.

The Development of the LS50

Introduction

Much progress has been made over the 35 years since the LS3/5A was developed. Computer-aided modelling [3], computer-aided measurement [4] and scanning laser Doppler velocity measurements [5] were pioneered at KEF and Celestion. CNC manufacturing, rapid prototyping and modern materials are also available to today’s engineer, along with high power computing and modern software. The LS50 benefits from these technological advances and, also, the further 35 years of experience the KEF design team has gained since the LS3/5A. Furthermore, modern high bit-rate recordings are now in common use and digital media has at last come of age, along with high power amplifiers, allowing the potential for higher performance.

As a result of the improved performance of audiophile analogue and high bit-rate digital systems, it was felt that the focus should be on producing a system with very low colouration, relatively extended low-frequency response and high power handling. The aim was to reveal the fine detail and image focus that the best systems can provide on good recordings, but with a faster leaner bass. Although KEF has a long history of well implemented three-way systems, in the LS50 the benefits of a minimalist compact two-way system have been explored using a “no holds barred” approach, owing much to the work on the Concept Blade system.

The use of Modelling and Measurement in the Development of the LS50

The use of modelling in loudspeaker design started around the time the LS3/5A was being developed. Initially loudspeaker systems were analysed in terms of “lumped elements” in an equivalent circuit. The mass of the loudspeaker moving parts, the motor strength, the stiffness and damping of suspensions and enclosed air volume in the cabinet are all that is required to describe the low-frequency behaviour of a loudspeaker. Neville Thiele showed that loudspeakers could be considered as high-pass filters allowing known filter theory to be applied [6]. The extreme simplicity of these models is a virtue in that they clearly underline the basic principles of operation, allowing the gross characteristics to be predicted and designed in a deterministic manner. They are still an essential first step to designing a loudspeaker system.

Richard Small clarified the “lumped element” technique for closed boxes and reflex boxes adding all the information required for the designer to work in a deterministic way towards a target response [7][8]. At KEF this work was embraced; an extremely expensive digital fast Fourier transform (FFT) analyser and computer were purchased. This allowed measurement of loudspeakers in the time domain, modelling using “lumped circuits” and computer optimisation of crossovers to be carried out. The design of drivers, boxes and enclosures to achieve a target response became a reality.

Meanwhile, at Celestion, scanning laser Doppler velocity meters produced animations clearly showing the structural resonances in loudspeaker diaphragms and enclosures, making the complexities neglected by 'lumped element' models tangible for the first time [5]. Improved driver and enclosure designs resulted.

In 1992 the Gold Peak group bought KEF and Celestion, bringing together these two approaches to loudspeaker design.

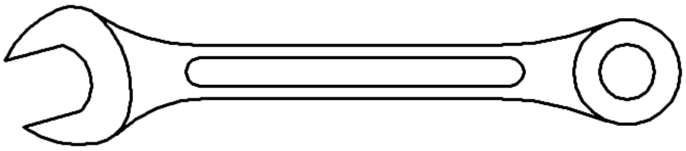
Mathematically, all acoustical behaviour is described using partial differential equations. The direct solution of these equations is only easily performed for a very few special geometric cases, such as the radiation from a flat rigid piston or the propagation of waves in a straight cylindrical duct. It is possible to approximate the behaviour of complex acoustical systems by using combinations of these special cases. This type of analysis can be very powerful as the equations are often soluble concisely, and from these concise solutions a great deal of information can be learnt about the underlying acoustical behaviour. However, it is only through the application of numerical techniques that the designer is free to analyse arbitrary shapes and geometries to within decibel accuracy.

Finite element analysis (FEA) is a numerical technique for modelling many different types of physical behaviour, such as acoustics, vibration, magnetism, electricity and thermal behaviour. A simple mechanical example of FEA is shown in Figure 1. FEA not only gives a results for “spot values”, such as the pressure at a point, but also provides the pressure at all points and allows the visualisation of sound to help the engineer understand the physics involved [9]. The wealth of information produced by this technique, along with its ability to deal with iterative changes to geometry, make it a natural choice for design.

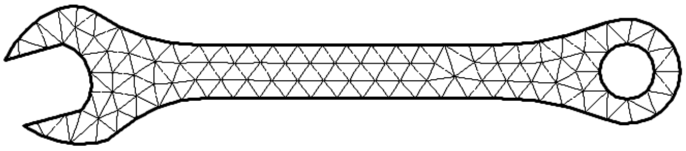
To model the sound radiation into infinite spaces, another numerical technique, boundary element analysis (BEA), is used. To model drivers and enclosures fully, a BEA model of the radiation environment may be fully coupled to a FEA model of the driver or enclosure.

The application of FEA is not straightforward: it has taken a couple of decades for the research team at KEF to progress from analysing the static behaviour of axisymmetric magnets in two dimensions to being able to carry out appropriate modelling of non-axisymmetric drivers and enclosures in three dimensions. The skills to do this are not trivial and encompass many disciplines, furthermore a significant financial investment is required both to purchase software and allow engineers time to acquire the necessary body of knowledge. At KEF, in-house software allows results from vibroacoustical FEA/BEA to be visualised and responses at chosen points viewed. Most significantly the software enables results from magnetic FEA, mechanical FEA and analytic models to be combined producing virtual prototypes of loudspeaker drivers and systems. This gives the KEF engineering team unrivalled power to explore new innovations and designs.

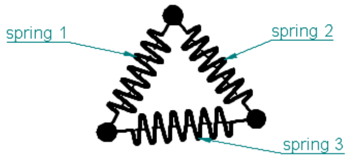
1. Geometry of object for analysis, in this case a spanner



2. The geometry is split into simply shaped elements



3. For each element the computer uses a simplified approximation to the underlying behaviour



4. This results in an accurate approximation of the overall behaviour

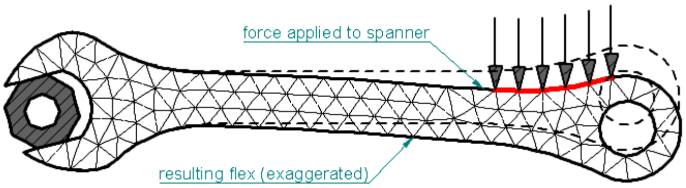


Figure 1. Finite element analysis illustrated for a mechanical analysis of a spanner.

Driver Selection

The LS3/5A drivers were exceptionally well refined for the time, using somewhat stiff and well damped materials. However, the driver diaphragms do not move as rigid bodies over the upper part of their frequency range. Such traditional diaphragms rely on having resonances and damping optimised for a clean sounding tonal response, but none the less they impart their own tonal characteristics to the sound.

The Uni-Q driver array selected for the LS50 is only similar to the LS3/5A in that it has a 5" nominal diameter midrange unit. This driver array produces a smooth and wide dispersion response with diaphragms behaving close to rigidly over their working bands. It produces exceptional point-source characteristics of great purity, both tonally and spatially. The midrange driver incorporates a mechanism to damp the diaphragm resonances, so the usual large peak found in metal diaphragms is absent from the response. Aluminium magnet rings are provided to reduce flux modulation and the corresponding midrange distortion. A Z-Flex surround ensures that the surround does not cause an excessive discontinuity for sound radiated from the high-frequency driver.

The high-frequency driver is derived from the Blade and uses a similar waveguide design to produce an apparent point source at the cone apex. This is achieved by means of a combination of patented technologies: The “optimal dome waveguide geometry” allows extended high-frequency response from a shallow spherical cap diaphragm at the apex of a conical wave guide [10]. The “tangerine waveguide” uses radial air channels to produce spherical waves up to the highest frequencies allowing a deeper “stiffened dome” diaphragm [11]. The increased depth raises the first diaphragm resonance resulting in a response that extends beyond 40kHz with wide dispersion and good efficiency. The unit also has a rear venting tube with a carefully optimised acoustical foam filling to avoid non-linearity and the associated distortion.

It is worth mentioning the new driver has significantly lower power compression and higher power handling than the LS3/5A drivers, due to the relatively large diameter voice coils, high temperature polyimide formers and long voice coil of the mid/bass unit.

The development of the LS50 has presented an interesting engineering opportunity to explore the audio performance potential of this driver array. It is perhaps not surprising that during the course of the LS50 development a number of minor refinements were made to the driver array, such as altering the voice coil to achieve the desired low-frequency response and improving some of the acoustic and mechanical damping.

Low-Frequency Alignment

The LS50 engineering project began with some initial “lumped element analysis” followed by the building of a number of prototypes to explore the balance. It was found that a reflex-loaded enclosure with a somewhat over-damped alignment, tuned to 55Hz, allowed music to be reproduced at satisfying levels with some low bass without losing the impression of clarity. The gentle roll-off from below 100Hz also gives good flexibility to position the speakers in smaller rooms where the boundaries will provide some bass lift.

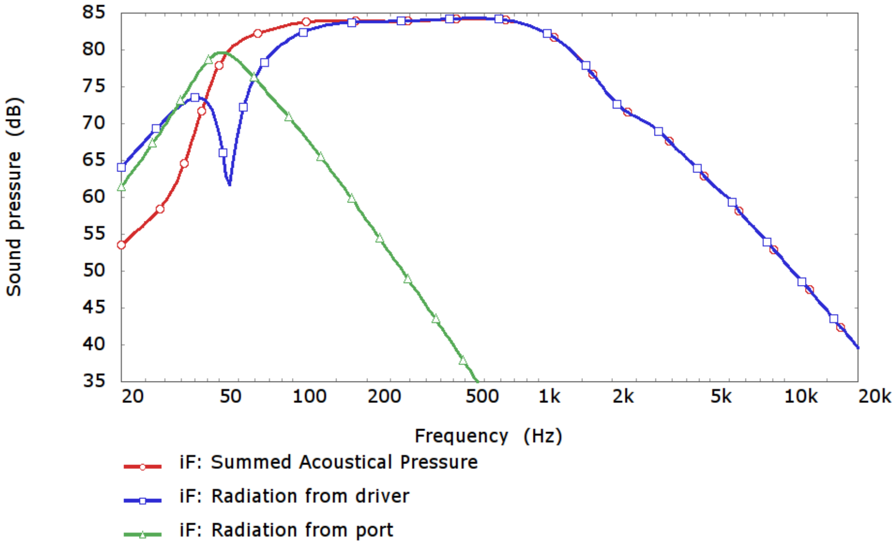


Figure 2. System response modelled with "lumped elements".

It is worth noting that the effect of bass level on the perceived sound is not straightforward. A psycho-acoustical phenomenon called spectral masking must be considered: quiet sounds will be concealed by similar-frequency louder sounds. This effect is particularly strong when a loud low-frequency sound is present along with a quiet midrange sound. Reducing the level of the low-frequency sound reveals the midrange sound and so a decrease in bass benefits the perceived detail. Since the transient part of bass lines is also somewhat emphasised bass rhythm is especially easy to follow.

The decision to use a reflex enclosure led to some engineering challenges that required much time and effort to overcome. The initial design used two folded port tubes located near the bottom corners of the enclosure and the driver centrally positioned in the horizontal plane, 2/3rds of the way up the enclosure. Subjectively the design had some promising qualities: the bass was tight, well extended and could go satisfyingly loud. The midrange sound was reasonably clean but not quite to the desired standard. Detailed measurements showed defects due to structural resonance of the enclosure and unwanted port radiation above the tuning frequency. While it was decided to proceed with an enclosure of this low-frequency alignment, it was felt necessary to do some extra work to improve the midrange performance.

Enclosure Design

Other than the output from the drivers themselves and port output due to the tuning frequency, any secondary radiation from the loudspeaker is undesirable and will cause colouration. With the majority of loudspeaker enclosures, there are some frequencies where the enclosure walls move and radiate some sound. This wall motion may either be caused by air pressure in the enclosure or due to vibration transmission from the driver.

For the initial design, “lumped element” models, with an approximate calculation for diffraction, were used to model the driver and port output, and determine the necessary driver parameters. FEA modelling techniques were then used to produce a detailed model including accurate calculation of diffraction, standing waves, wall motion due to acoustical and vibrational excitation and port output. Where desired, these may be calculated independently. This gives shorter calculation times and allows the impact of each mechanism to be separated. Furthermore, the sound pressure and vibration may be visualised on a computer, giving great insight into the mechanisms and allowing efforts to be focused on the areas requiring most improvement.

For this detailed modelling, 3D CAD models were used to directly generate FEA models allowing vibration and the internal acoustics to be calculated. These FEA models may be fully coupled to BEA models of the radiation environment allowing the sound output from the enclosure and drivers to be calculated. Where the enclosure has symmetry, only part of the system need be modelled since sound and vibration will also be symmetrical. The acoustic performance of different geometries, structures and materials may then be fully explored.

Vibroacoustical Analysis of the Enclosure

The reactive force on the driver magnet, due to current passing through the voice coil, is source of vibration which causes the enclosure walls to vibrate and possibly to radiate as an unwanted secondary sound source. Because the enclosure walls are resonant, this radiation has large peaks and decays slowly. This results in colouration and masking of detail.

The most effective technique for avoiding this radiation is force cancelling, where two identical drivers rigidly coupled together are driven with the same signal. In this case, the reactive forces are equal and opposite so cancel and no net vibrational force is produced. An alternative method of preventing the reactive force reaching the enclosure is to use decoupling where the driver is connected to the enclosure by a soft material that reduces vibration transmission.

For loudspeakers with a single driver, force cancelling is not an option. Decoupling provides effective vibration control for midrange drivers, but is not readily achievable for drivers covering the low-frequency range. The very soft materials required would not provide adequate support for the driver. As a result, an alternative approach is required for two-way loudspeaker systems

To illustrate the effect of enclosure vibration, results from an early design are shown below. This design has one plane of symmetry, so only half the enclosure need be modelled. Using FEA one can look at the enclosure radiation due to the reactive force in isolation.

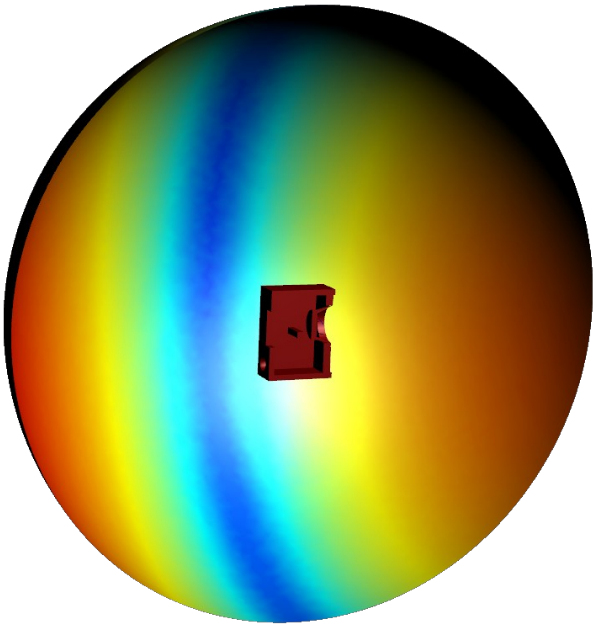


Figure 3. FEA model of enclosure showing displacement and pressure due to reactive force at 200Hz

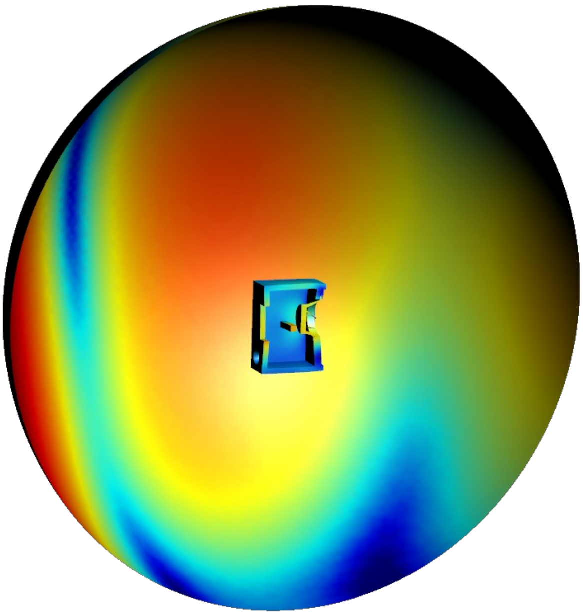


Figure 4. FEA model of enclosure showing displacement and pressure due to reactive force at 1009Hz

At low frequencies the box simply moves backwards and forwards: the model does not include any constraints to 'anchor' the enclosure. Since the wavelength at this low-frequency is much larger than the enclosure, this type of motion results in a dipole radiation characteristic. FEA results for this case are shown in Figure 3. The enclosure is moving as a rigid body and is consequently one colour. The sound pressure is displayed on a hemisphere around the enclosures. The the null pressure region that one would expect from a dipole source can be seen. In practice this rigid-body motion may be controlled by the use of a high mass stand, preferably sand filled to absorb some of the vibration. The FEA results for the first highly coupled structural resonance at 1009Hz are shown in

Figure 4. The enclosure is now moving in a much more complicated manner and the radiation is no longer simple.

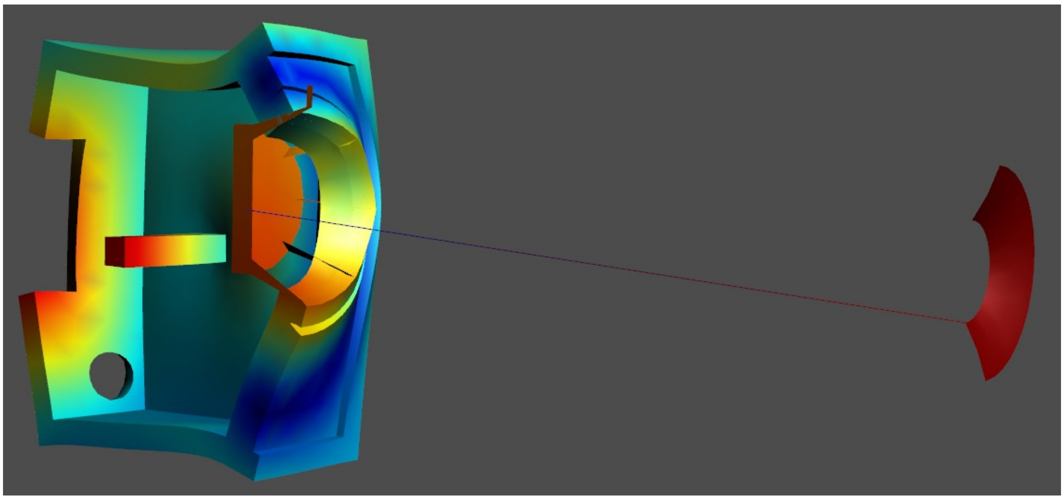


Figure 5. Results from FEA model of early prototype of LS50 showing diaphragm and walls displaced with colour also representing displacement at 1009Hz

Figure 5 shows a close up of the enclosure at this frequency, with the geometry displaced by an exaggerated amount to make the result easily visible. The diaphragm is also shown with its displacement scaled by the same amount. It is interesting to note that, due to the large area of the enclosure walls, this enclosure resonance causes a 2dB peak in the modelled response even though the diaphragm is moving much further than any other part of the loudspeaker.

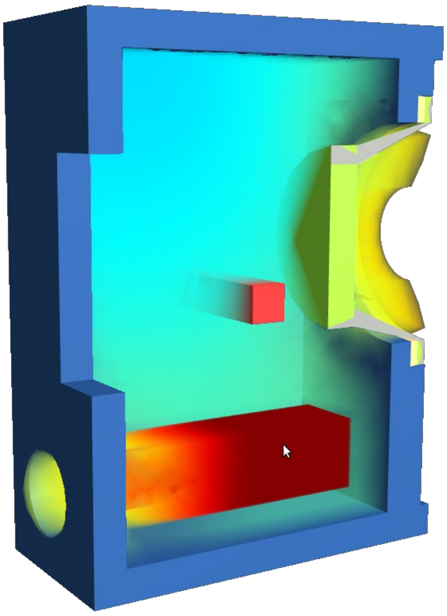


Figure 6. FEM calculated air pressure in enclosure at 476Hz

The pressure inside the enclosure was also modelled. The most notable issue was the presence of longitudinal resonances in the port tube. The initial port was a folded design with a circular tube going from back to front and external box section outside the tube going from front to back. Figure 6 shows the pressure: the port is red indicating very high pressure in its middle section. Figure 7 shows the acoustic radiation from the port with a microphone placed 1cm from the port. From 400HZ upwards the peaks in the response are due to longitudinal resonance.

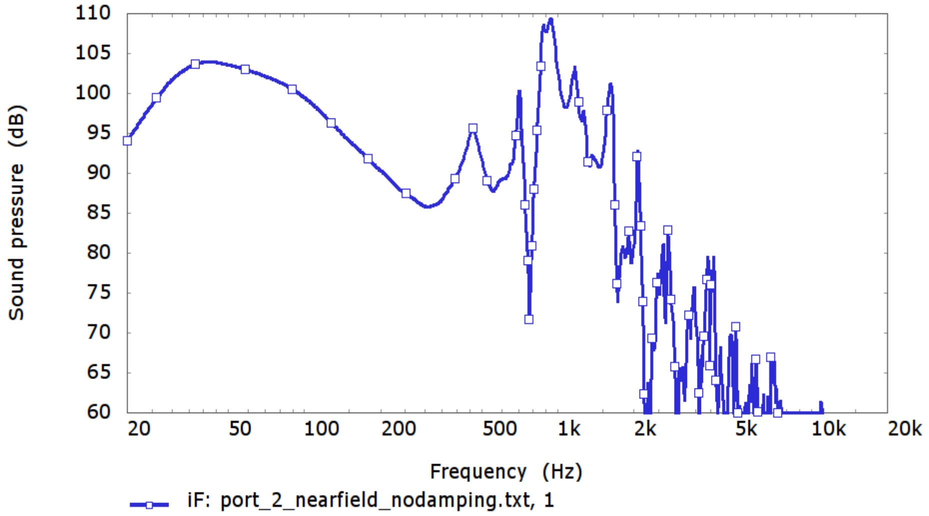


Figure 7. Measured port output from early prototype, near-field microphone

Reducing the Enclosure-Wall Vibration

An initial FEA/BEA model was created without braces or port to separately evaluate the diaphragm and enclosure-wall output. This was achieved with the enclosure walls excited only by internal air pressure and then with the walls excited by the reactive force on the magnet. The results are shown in Figure 8. It can be seen that in such a small enclosure, with relatively thick walls, the internal air pressure produces acoustic output which is almost 40dB lower than the diaphragm output.

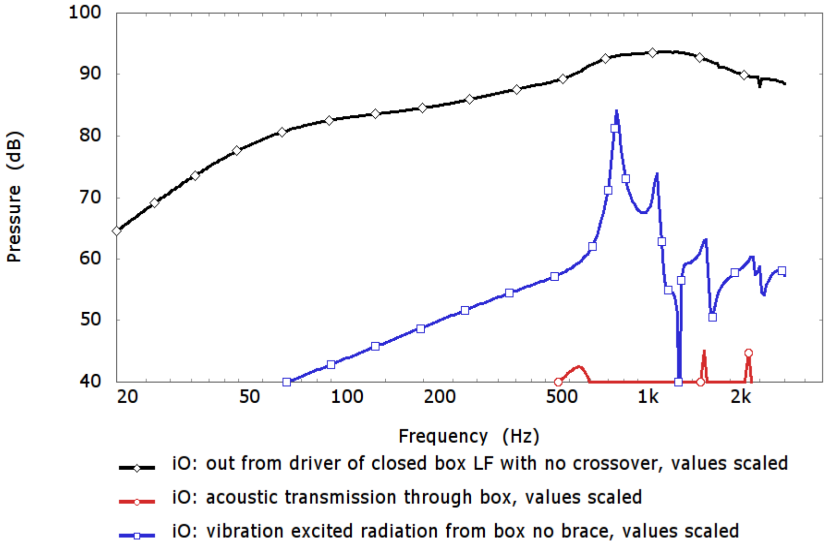


Figure 8. Closed box FEA/BEA predicted output from diaphragm, walls driven by vibration and walls driven by internal air pressure.

A brace positioned centrally on the plane of symmetry cannot buckle: in effect the symmetry adds stiffness to the brace. A brace placed on one of the enclosure the planes of symmetry centrally supports the enclosure walls. A pair of braces, crossing behind the driver, were added to the model in an attempt to prevent the lowest enclosure resonance. However, while the resonance was raised to a higher frequency, its amplitude was not reduced relative to the driver. Indeed the frequency is raised towards the ear's most sensitive region. The resulting enclosure output predicted by a FEA/BEA model is shown in Figure 9.

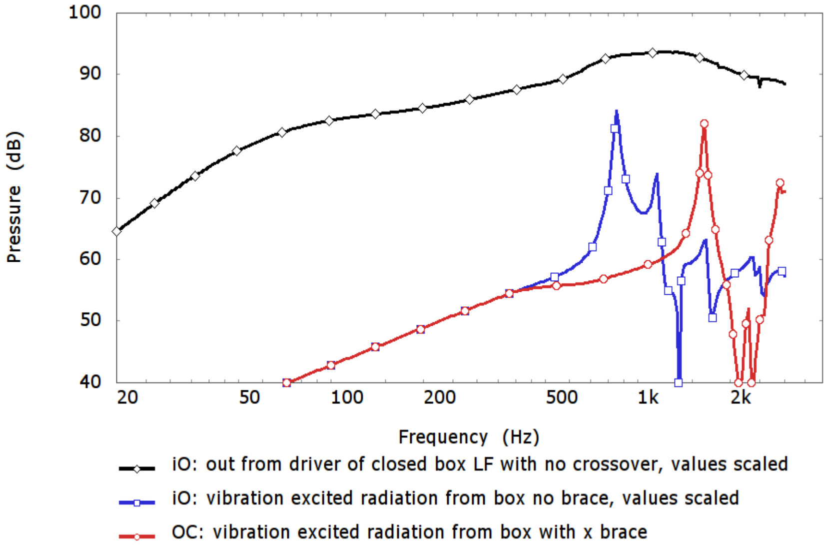


Figure 9. Closed box FEA/BEA predicted output from diaphragm & walls with and without x-brace.

It was found that adding material with high mechanical resistance and low stiffness between the walls, baffle, driver and brace results in extremely effective suppression of the resonances. This arrangement proved highly effective at damping the wall resonances as can be seen from the modelled result shown in Figure 10. As with the BBC approach, using thick damping pads, the frequency of box resonances is not increased. However, the KEF approach allows a theoretical reduction in cabinet vibration of about 30dB which is approximately 20dB greater than could be expected with conventional damping material directly attached to the panels.

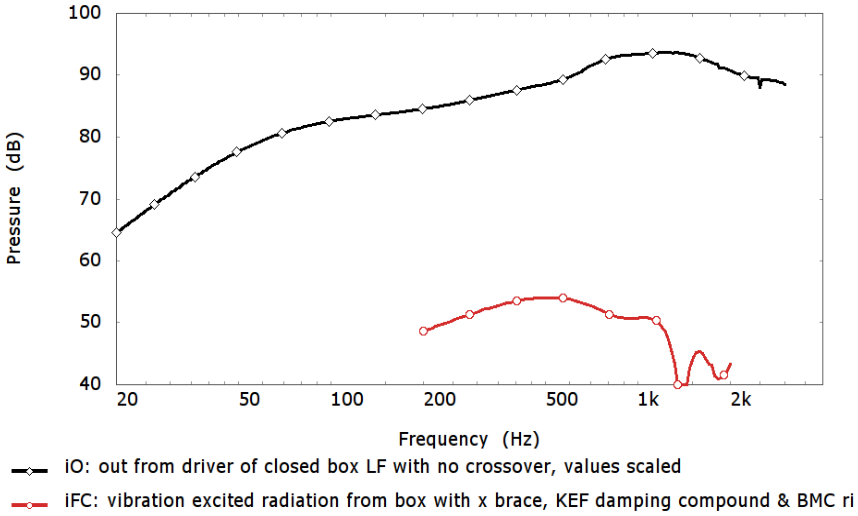


Figure 10. Closed box FEA/BEA predicted output from diaphragm & walls with constrained layer of damping material between brace and walls.

To illustrate these results in practice, some spot measurements were taken with a laser Doppler vibrometer of the rear panels of three loudspeakers. Figure 11 shows a cumulative decay spectrum (CSD) of the rear panel velocity of a budget chipboard enclosure. Three panel resonances can be seen, the one at 250Hz has an initial level of 47dB and is still visible within the 30dB display window after 50ms.

By comparison it can be seen from Figure 12 that the LS3/5A fares much better, the three resonances between 300Hz -400Hz have a level of 38dB and have decayed to below the display window minimum after 30ms.

Figure 13 is a CSD of the LS50 enclosure velocity. It shows what appears to be rigid body motion which decays rapidly. The resonant tails appear to indicate a level of about 23dB showing a very significant improvement on both of the other enclosures.

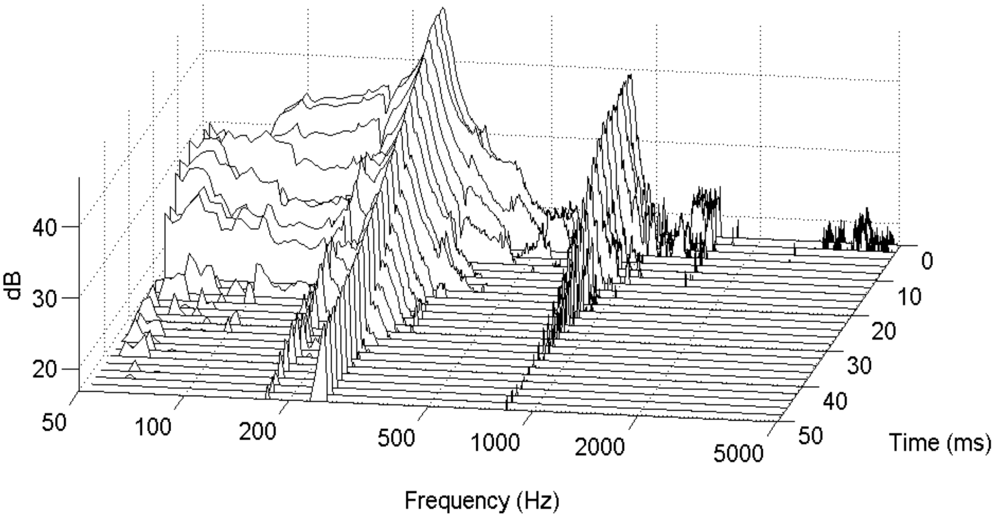


Figure 11. Budget chipboard enclosure spot velocity measured with laser Doppler vibrometer.

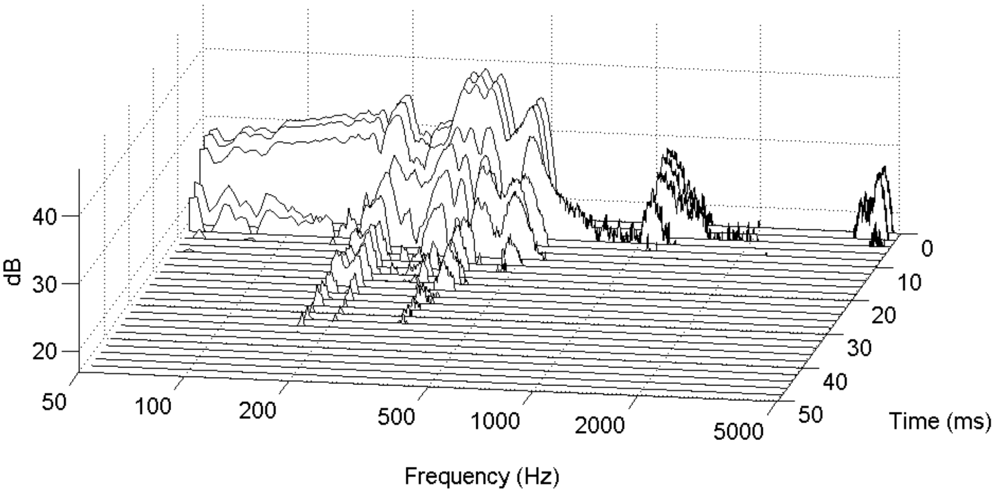


Figure 12. LS3/5A enclosure spot velocity measured with laser Doppler vibrometer

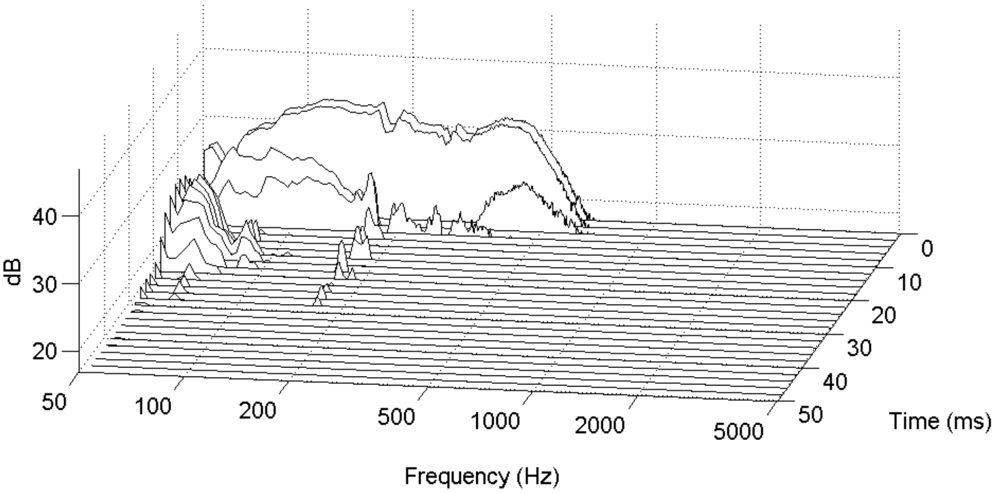


Figure 13. LS50 enclosure spot velocity measured with laser Doppler vibrometer

Controlling Enclosure Standing-Waves

Acoustical cavity modes, or standing-waves, can cause response deviations of the driver motion and also unwanted response peaks in the output of the port. Using FEA it is possible to calculate the pressure distribution and frequency of the resonances in a volume of air due to standing waves. Figure 14 shows the FEA calculated pressure magnitudes of the first six cavity resonances for a volume of air enclosed by rigid boundaries. The blue regions are high pressure and the green regions are low pressure. A central position of the driver on the left hand side face will be in the low pressure region and thus avoid exciting five of these resonances

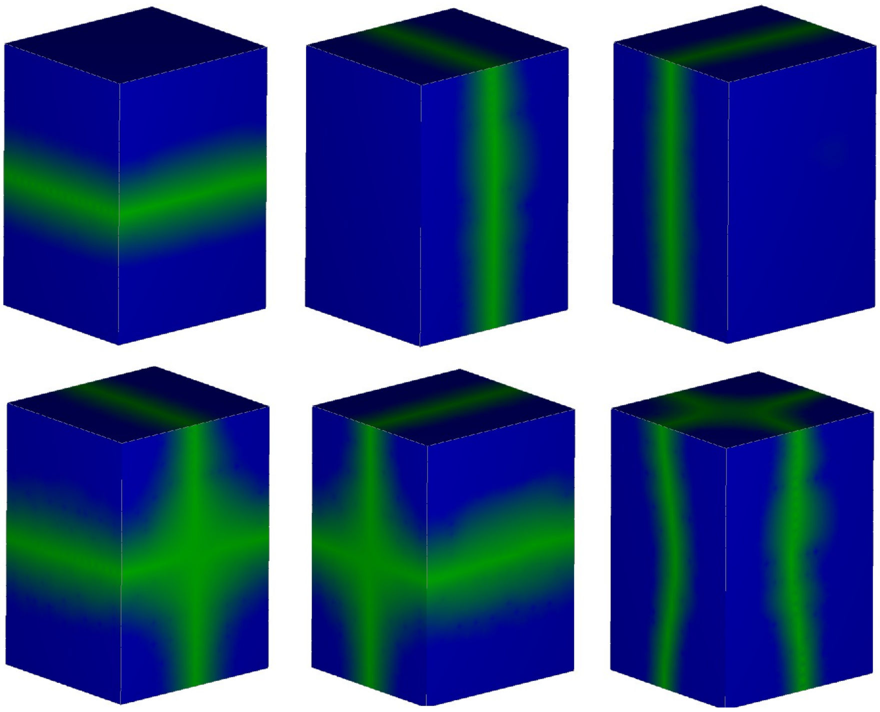


Figure 14. Magnitude of pressure for cavity modes in a rectangular volume of air bounded by rigid walls

Given the limited number of modes excited by adopting this driver position, acoustic damping material may then be optimally positioned to maximise the reduction of the remaining resonances. A similar approach may also be applied to the port position: this is a subject of a patent application so will not be discussed further here.

Enclosure Baffle Diffraction

Another consideration in the enclosure design is finding the best shape of front baffle to mitigate the effects of diffraction. The use of one of the latest generation Uni-Q drivers with "optimal dome waveguide geometry" and the "tangerine waveguide" ensures wide and even dispersion without interference between drivers. Experience from the work on the Blade showed that avoiding reflections and diffraction was key to revealing the full spaciousness and stereo image of recordings.

Enclosure diffraction may be modelled using BEA. Since the geometry of the LS50 is symmetrical in two planes, only a quarter model of the enclosure is necessary. The results of one such model for a single solution frequency are shown in Figure 15, with the amplitude of the acoustical waves represented by displacement and colour. The pressure on the symmetry planes has also been calculated to illustrate the effects of diffraction.

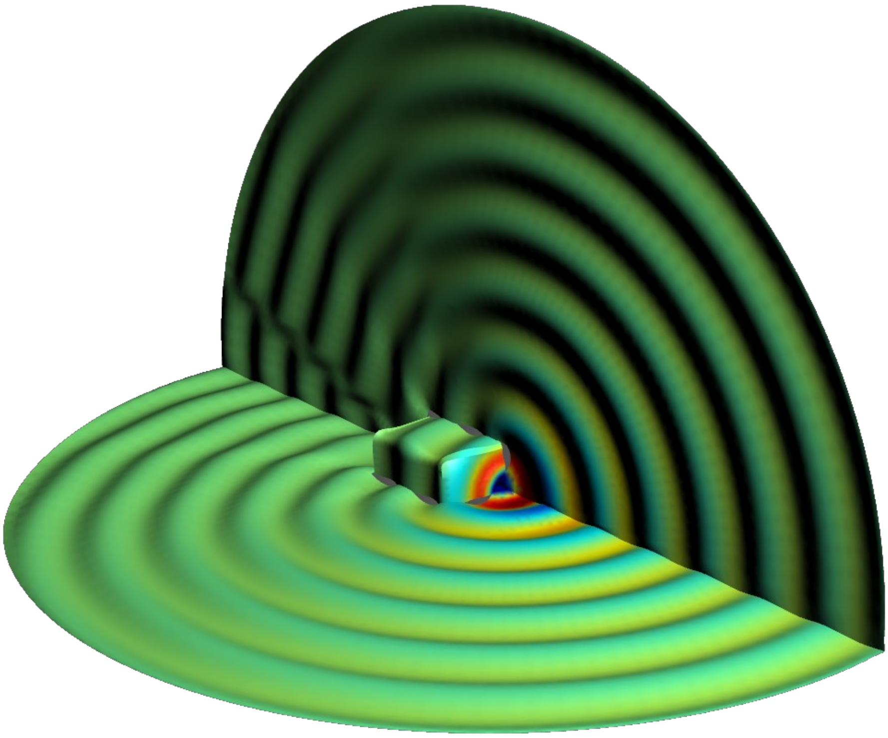


Figure 15. BEA model of 1/4 enclosure at 2,450Hz showing wave propagation.

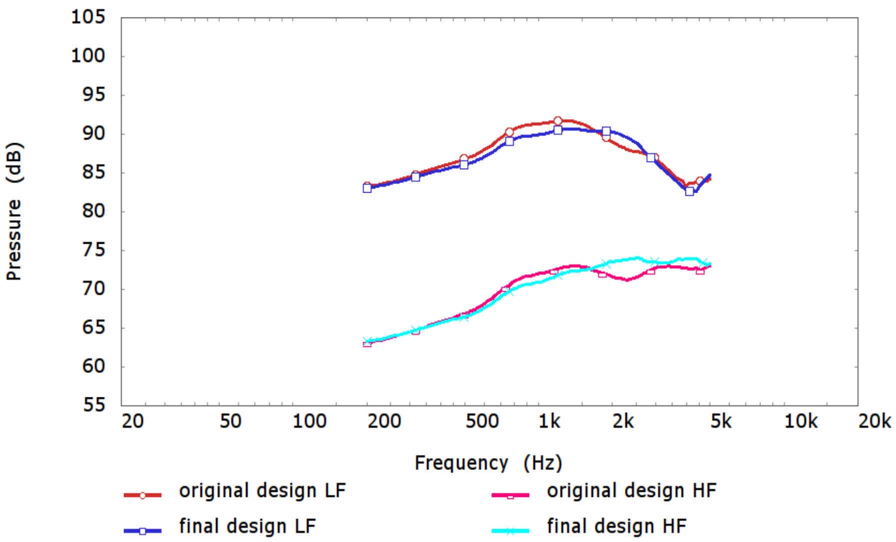


Figure 16. BEA calculated axial response of idealised LF and HF drivers

A variety of geometries, ranging from rectangular enclosures to more complex shapes, were analysed and the axial frequency response of idealised mid-range and high-frequency drivers evaluated. The geometry was refined over a number of iterations to produce the smoothest response in the hemisphere in front of the loudspeaker. The initial and final axial responses are shown in Figure 16.

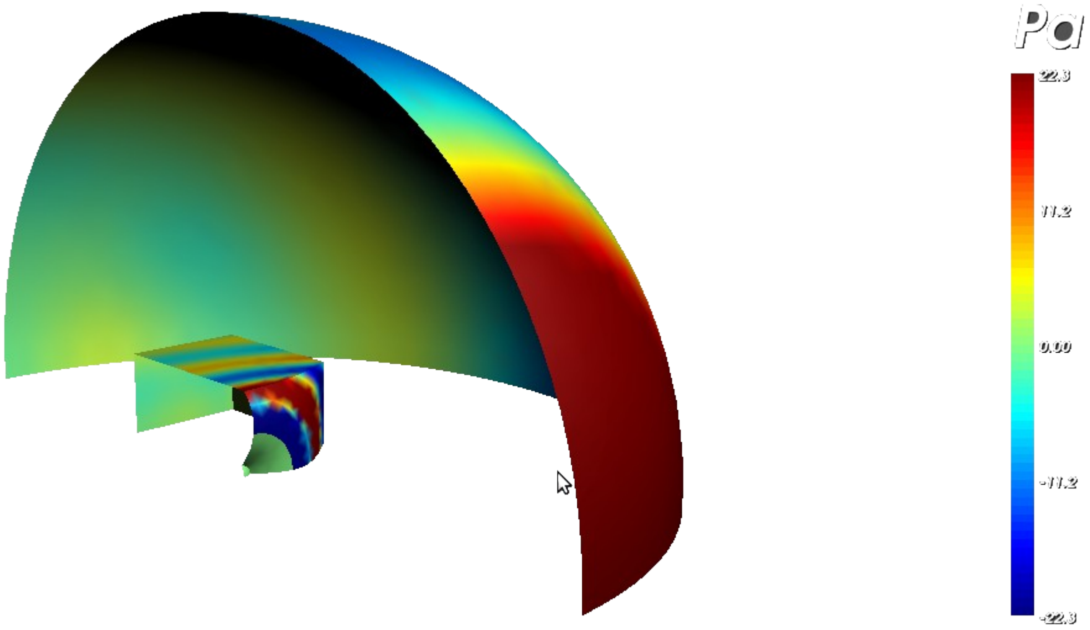


Figure 17. BEA model of cabinet showing pressure on enclosure and display sphere quadrant.

Port Design

The purpose of a reflex port is to act as an acoustic mass that, together with the compliance of the enclosed air volume, forms an acoustic resonator. However, in a practical loudspeaker it is necessary to consider a number of other issues as well. Firstly, the air flow must not become turbulent at high levels since this causes distortion and power compression.

Work carried out at KEF, using computational fluid dynamics (CFD), has shown that using a suitable port profile does much to control turbulence allowing the bass output of the system to fulfil its potential.

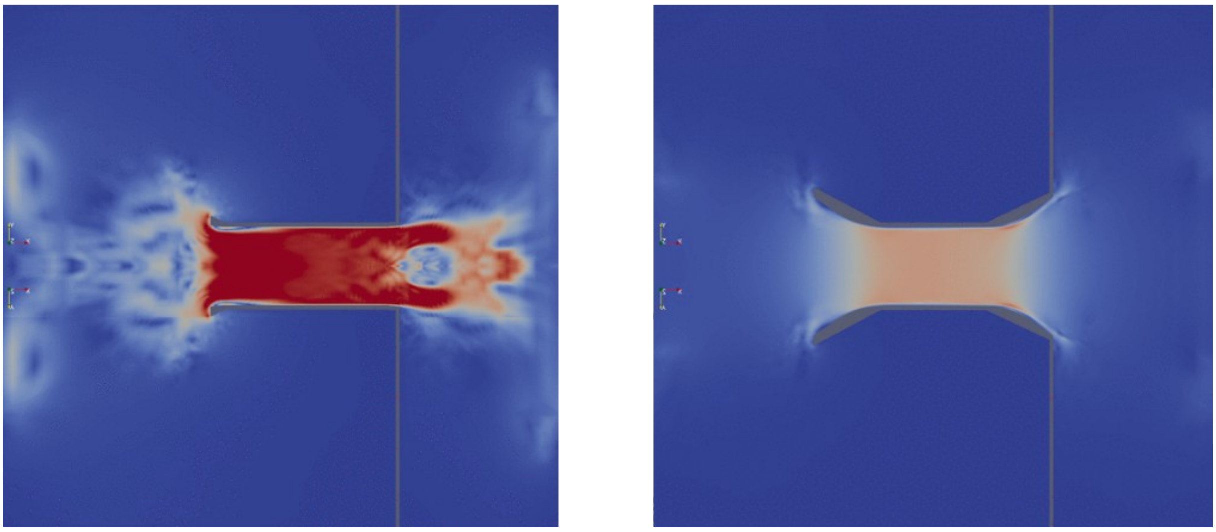


Figure 18. CFD modelling of different port geometries to show turbulence

Secondly, where the wavelength of sound is a multiple of half the port length, longitudinal resonances in the port tube occur which radiate unwanted acoustic output as can be seen in Figure 7. This output tends to be in the midrange and causes similar colouration and masking effects to the box vibration.

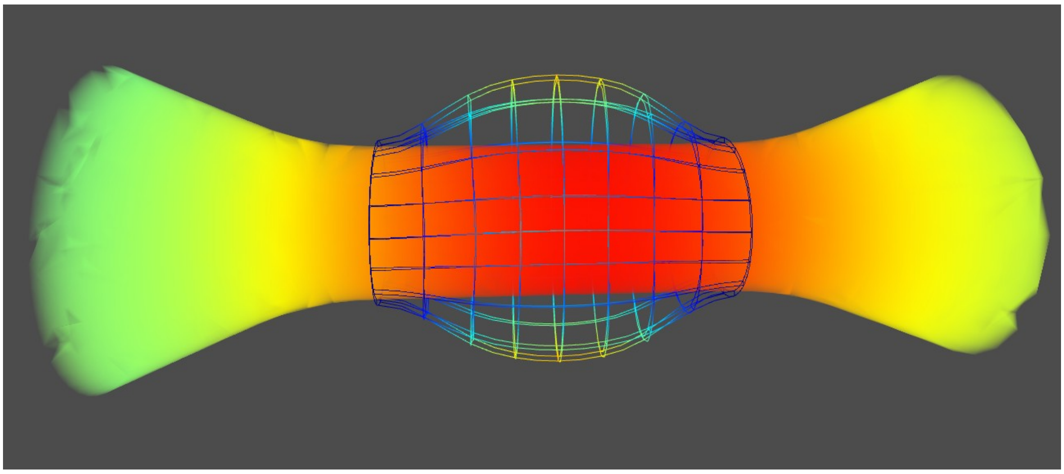


Figure 19. Air pressure in port tube showing longitudinal resonance and mesh of flexing wall

Reducing the magnitude of the longitudinal resonances cannot simply be achieved by filling the port with acoustic foam since this would reduce output in the bass region and prevent an efficient alignment. An alternative method to control the longitudinal resonance was devised for the LS50, by creating a port with flexible walls. This is achieved by fabricating the middle part of the port from carefully selected closed-cell foam. At midrange frequencies the port walls allow sufficient sound to escape for the resonance to be reduced by as much as 15dB with little effect at low frequencies. Figure 19 shows the air in the port at resonance, the red colour indicates high pressure. The mesh of the flexible wall can be seen with the motion exaggerated. The effect on the port response, in Figure 20, is that the unwanted port output is reduced by 15dB. The rear orientation of the port gives a further reduction in this colouration, so in total it is approximately 30dB lower than the driver midrange output at the listening position. The above design approach is the subject of another patent application. The complete design is shown in Figure 21.

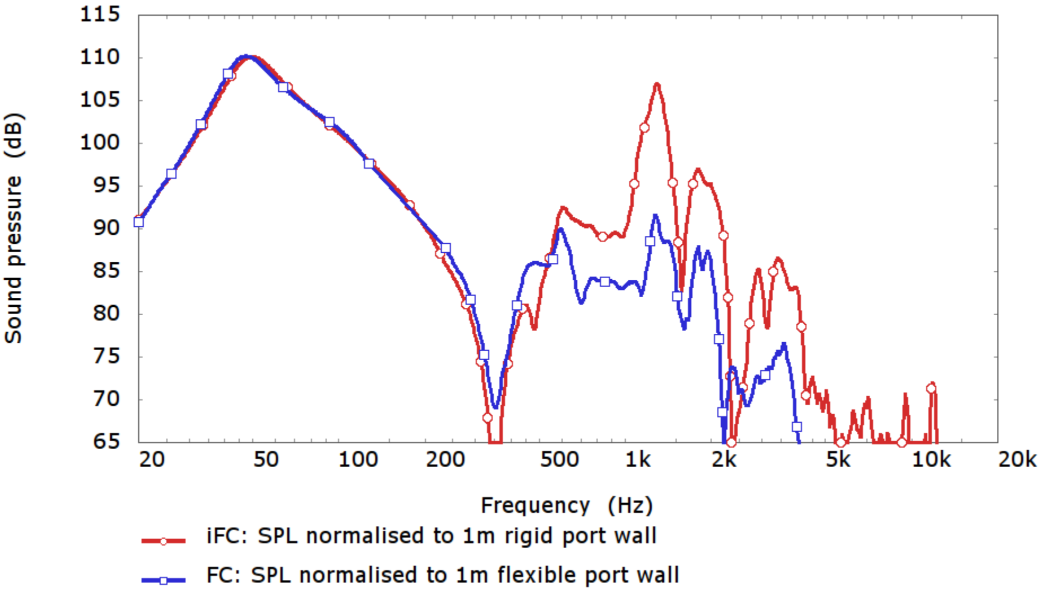


Figure 20. Measured nearfield port radiation for rigid and flexible tubes

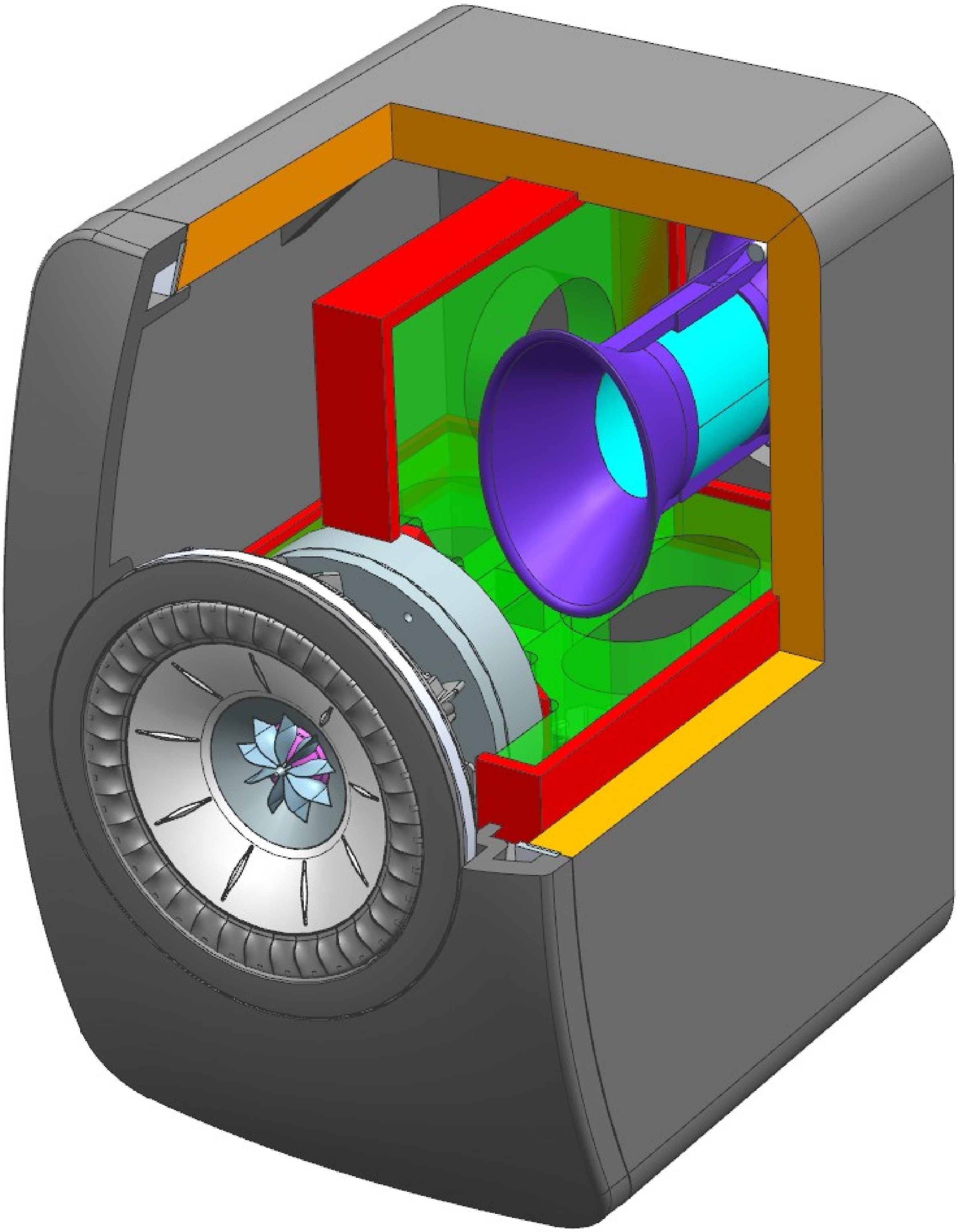


Figure 21. LS50 with cutaway section showing flexible port (cyan), cross-brace (green) and damping mastic (red).

Voicing the Loudspeaker

The crossover was initially designed from measured responses of the individual drivers mounted in the final enclosure. It was found that the combined driver response and diffraction characteristics required a relatively sophisticated circuit: after all the aim was for a smooth response not for the flattest response. It is perhaps worth noting that during the balancing process the priority was on the subjective performance not obtaining the flattest response.

The acoustic balancing of the LS50 was carried out by the KEF listening panel. There are some passing similarities to the methods used for the LS3/5A. Some use was made of anechoic voice recordings of KEF R&D team members since this is a very sensitive way of checking for colouration. Additionally, a wide range of commercial music recordings were used to evaluate the balance. The reference loudspeakers used were the LS3/5A and the KEF Blade (production version).

The key components for the crossover were individually auditioned to ensure they did not limit the perceived sound quality. The capacitors for the higher-frequency section are vibration damped with mastic, to prevent sonic deterioration due to vibration. Initial prototypes were bi-wired but during the voicing it was found that the system actually sounded better with bi-wire loudspeaker cable connected together both at the amplifier and the loudspeaker. Consequently, the final product incorporates a single pair of binding posts. Nevertheless, the low-frequency and high-frequency circuits are on separate boards to reduce interaction between the inductors, since this has been found to have a significant impact on detail.

LS50 Performance Summary

The frequency response of the LS50 compared to the LS3/5A is shown in Figure 22. Perhaps unsurprisingly, the LS50 is somewhat more regular and slightly more efficient. Indeed, the LS50 response is slightly smoother 10 degrees off axis and in many cases this is a preferable listening position.

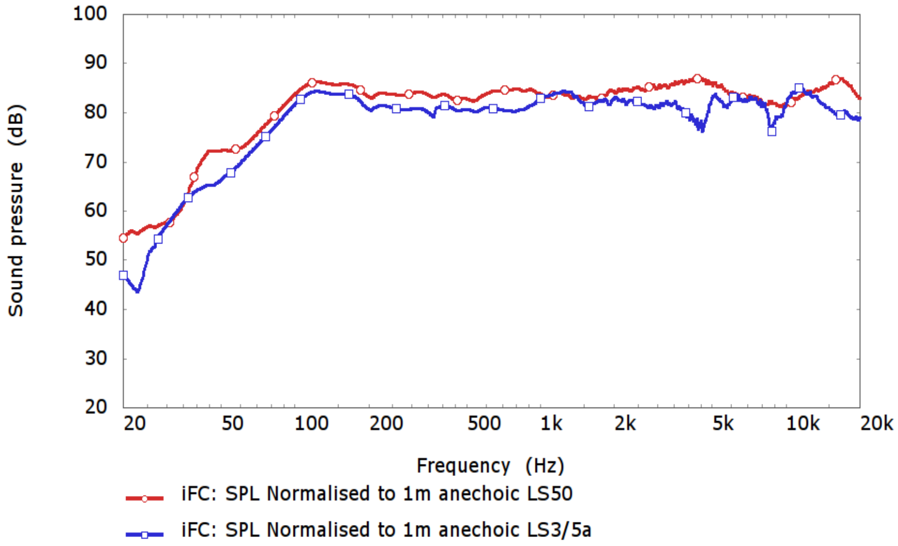


Figure 22. On axis SPL comparison of LS50 with LS3/5A.

Both horizontal and vertical polar data was measured for the LS50 and LS3/5A. Rather than displaying this as polar diagrams for a few frequencies, the more modern technique of showing a contour plot with contours 3dB apart is used to display the data. The vertical axis shows angle: the centre of the contour corresponds to the front or 0 degrees, and the top and bottom are directly behind the enclosure at +/- 180 degrees. Frequency is on the horizontal axis from 200Hz to 20kHz. Colours represent SPL, as shown on the legend on the right.

In Figure 23 and Figure 24 the polar response of the LS50 is shown. The -3dB contour narrows only slightly and has few irregularities. The remaining contours also narrow as frequency increases. From 500Hz to 1kHz some lobing behind the enclosure is evident.

For the purposes of comparison, the same data was acquired for the LS3/5A and is shown in Figure 25 and Figure 26. It can been seen that the LS3/5A becomes more directional between 1.5kHz and 4kHz due to the increasing directivity of the LF driver. The vertical polar response of the LS3/5A is much less regular than that of the LS50 due to interference between drivers at the crossover frequency.

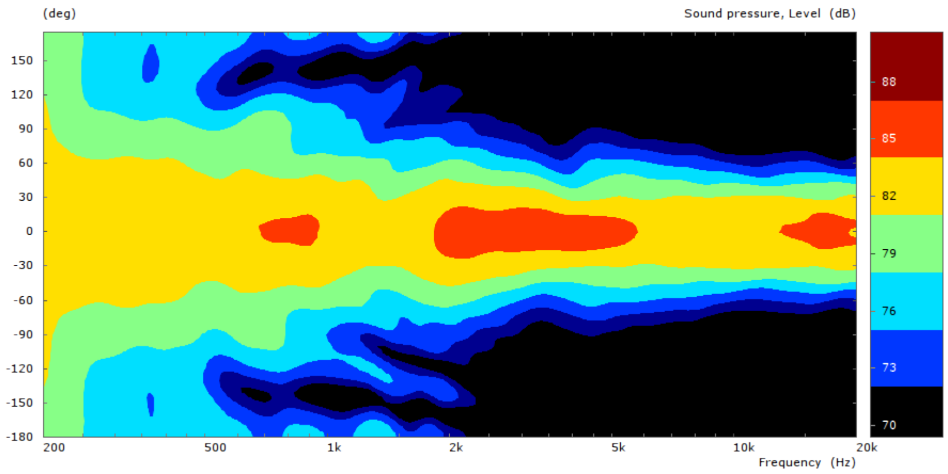


Figure 23. LS50 Horizontal polar data

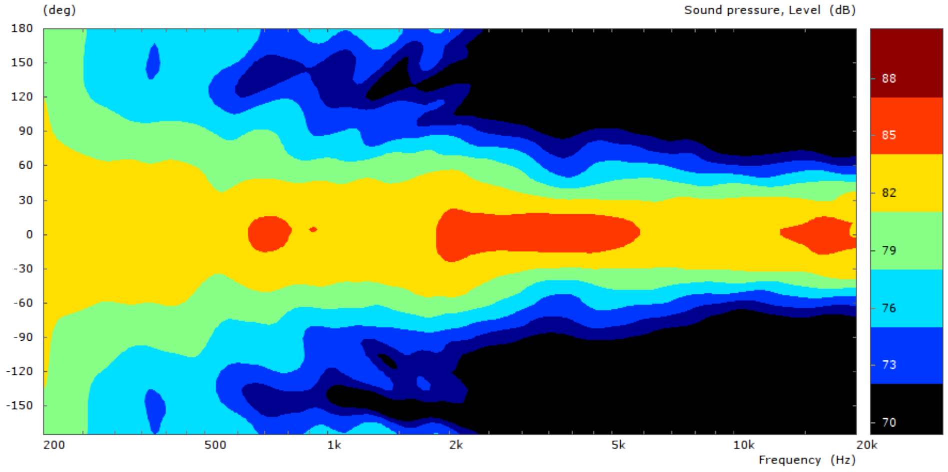


Figure 24. LS50 vertical polar data

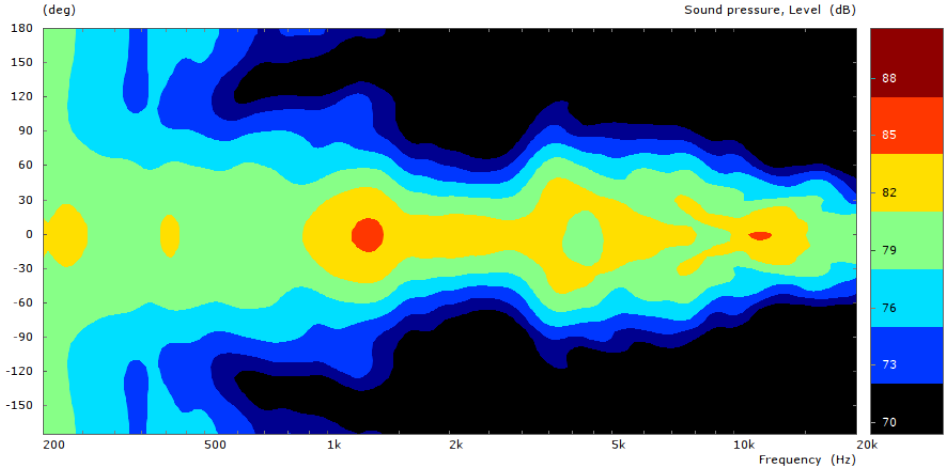


Figure 25. LS3/5A horizontal polar data

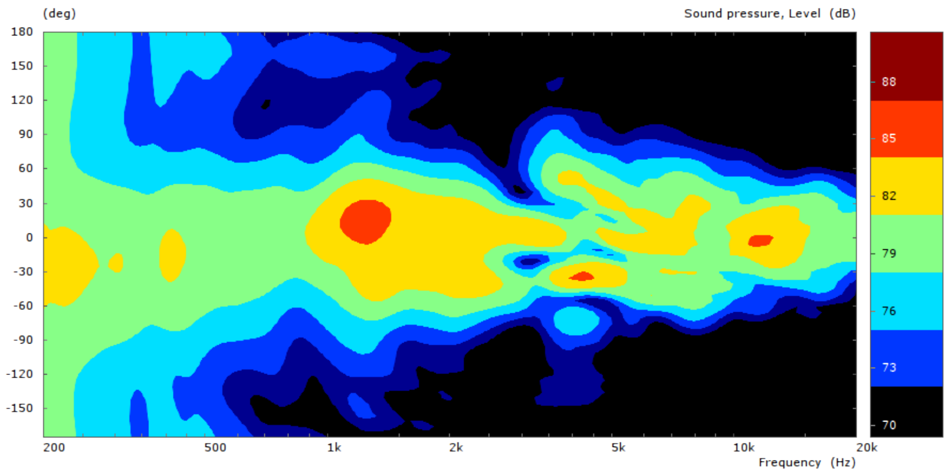


Figure 26. LS3/5A vertical polar data

The power response of the two systems are shown in Figure 27. It is interesting to note that the power response of the LS50 is very much smoother than the axial response which was shown in figure 22.

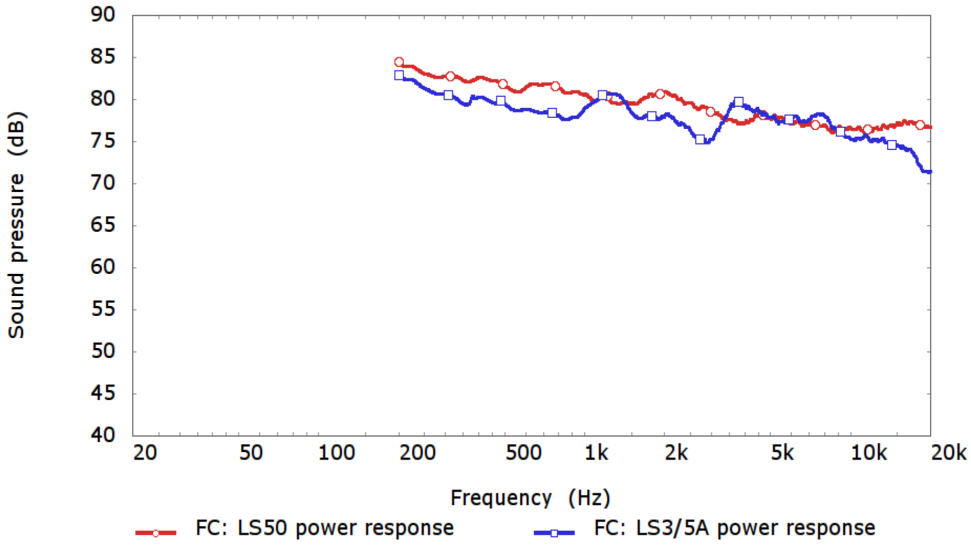


Figure 27. Frontal power response of LS50 and LS3/5A

Finally, the cumulative spectral decay spectra of the LS50 and LS3/5A are shown in Figure 28 and Figure 29. These are both relatively well behaved with no major enclosure ringing. The LS50 decay is extremely rapid for the first 10dB and is significantly cleaner at mid- and high-frequencies.

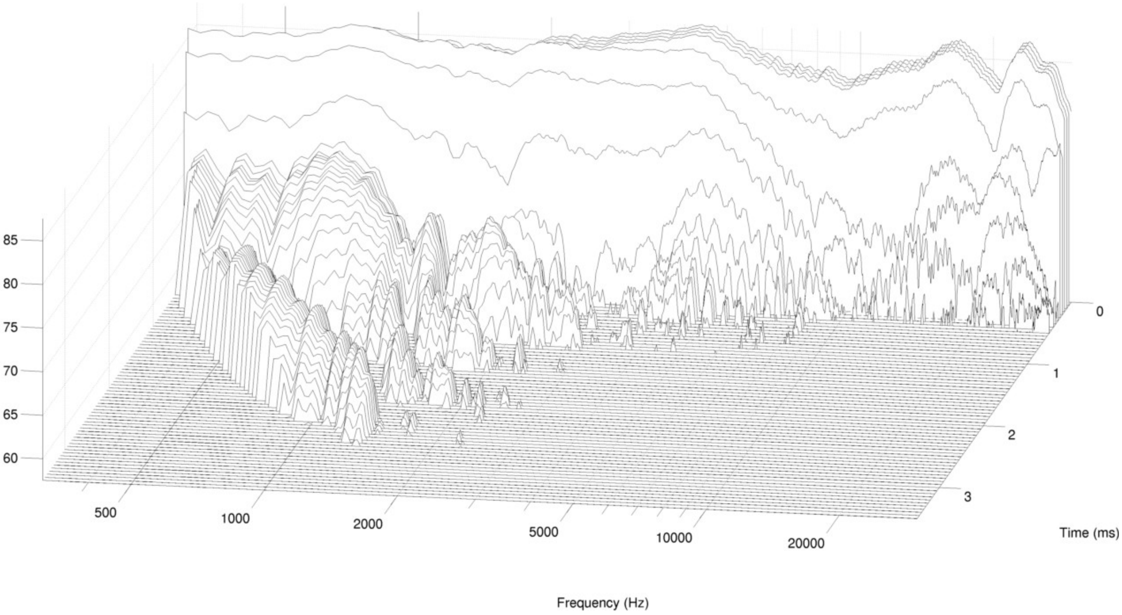


Figure 28. LS50 CSD

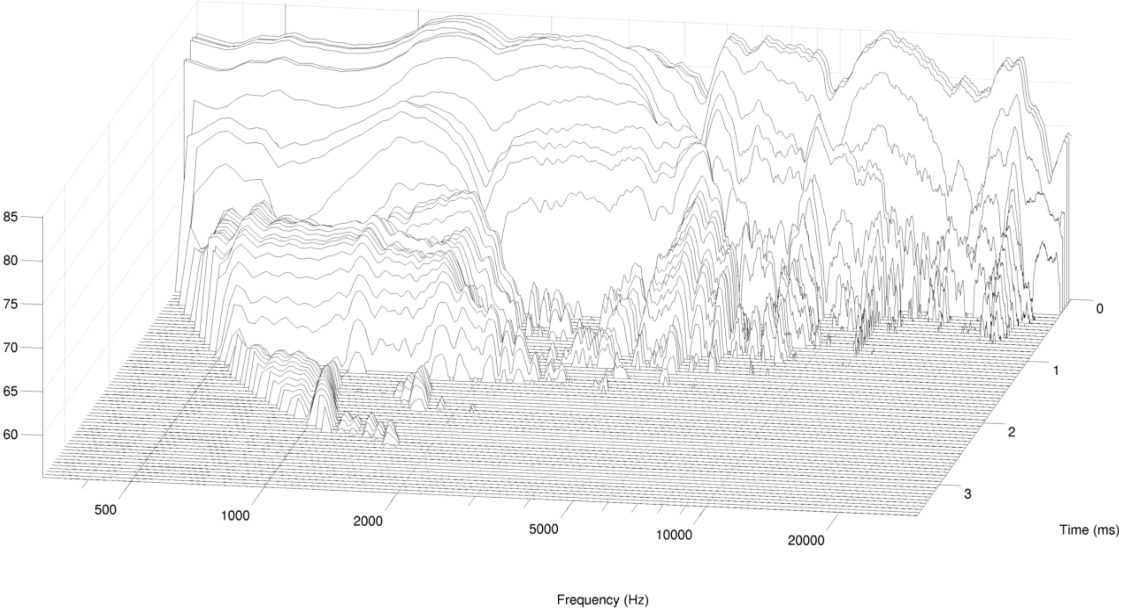


Figure 29. LS3/5A CSD

Conclusions

The development of the LS50 was based on a highly technological approach. Simulation and measurement is used wherever possible to identify, quantify and resolve performance shortcomings. This philosophy is classic KEF and is one which has been consistently applied over the companies 50 year history. The recent maturity of numerical techniques, such as FEA and BEA, make the approach more effective than ever – especially when guided by critical listening and engineering intuition. Recent products such as Blade, R-series and now the LS50 are testament to the efficacy of this process.

The LS50 uses a central driver position and computer optimised acoustical damping to avoid exciting resonances due to standing waves. A combination of bracing on the symmetry planes and constrained layer damping within the enclosure construction is extremely effective at absorbing the driver vibration and effectively eliminates cabinet colouration due to wall radiation. The baffle design provides a smooth response over the entire forward region, reducing tonal variation in different listener positions and ensuring the most spacious sound with precise stereo imaging. The port design has a profile optimised to avoid turbulence with the accompanying distortion and bass compression. A flexible section in the port reduces resonant midrange output from the port.

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