White Paper

Measurements on a SEAS H1207 Bass/Mid Driver:

Comparison of results between an IEC Baffle and both a TTC750 and a TTC350 Tetrahedral Test Chamber.

16 October 2015

Aim:

The aim of this report is to do comparisons between traditional IEC Baffle (configured as a ground plane) loudspeaker measurement and a Tetrahedral Test Chamber (TTC) and to review the suitability of using the TTC's for loudspeaker driver measurements throughout the supply chain.

Summary:

This report shows that both from a theoretical point of view and from measurements – that TTC's are capable of giving accurate, measurements within a relatively small physical size at a vastly reduced cost in manpower, both in time and skill required to achieve a repeatable result, and with reduced capital compared with traditional methods.

The measurements are shown to correlate very well with those from an IEC baffle however they are of higher resolution, not showing the rough responses of a typical IEC baffle measurements.

The use of a TTC will dramatically simplify setting measurement tolerances on loudspeakers by eliminating practically all of the modal effects of our current test enclosures. When used throughout the supply chain the TTC's have been proven to give consistency of acoustic measurements this leads to lower costs and higher quality products by eliminating the current situation of differing acoustic measurement set-ups at different stages with the resulting arguments and time wasting.

Background:

The Tetrahedral Test Chamber is a relatively new concept in loudspeaker measurement first introduced in 2013, it's aim is to provide a unified loudspeaker measurements that are small, stable, repeatable and convenient such that they can be used throughout the entire supply chain from design through manufacture, quality control and onward to the final customer. With rigidly defined measurement geometry together with interchangeable sub baffles they ensure rapid, accurate repeatable measurements time and time again. There relatively small physical size means that they are readily transported if required and easily set-up by one person.

What is a Tetrahedral Test Chamber?

Simply put it acts like your own mini-anechoic chamber. They take the form of a tri-rectangular tetrahedron which will fit neatly into the corner of a room.

A microphone is fitted inside towards the back corner of the chamber. The speaker to be tested is placed so that it fires into the chamber (at the microphone) - not out of it like a normal loudspeaker enclosure.
The loudspeaker is connected to an amplifier that takes its input from the analysis equipment hardware or software that you are using. The microphone is also connected to the same equipment allowing the test programme to check if what came out is what went in.

Because they use an arrangement that allows the speakers to be tested to always be fitted in the same position with respect to the microphone results are very accurate and repeatable.

The basis upon which the Tetrahedral Test Chambers (TTC's) have been designed is to minimise errors in loudspeaker driver measurements whether they be set-up inaccuracies or internal reflections, the design is based upon a Tetrahedral structure with acoustic absorption at the walls/floor of the enclosure to eliminate any remaining high frequency issues.

The tetrahedral shape is more familiar as the Tetrahedron which is constructed by 4 identical equilateral triangles, however the tetrahedral shape used here is based upon 3 roughly right angle triangles which easily fit into a corner.

Equipment used and Test Methodology:

The TTC chosen for this report will be one of the medium versions (the TTC750 with a final comparison to the TTC350). The TTC750 has an approximately triangular footprint of 760mm x 760mm x 1100mm and is 800mm high (with feet); this version is suitable for loudspeakers up to 200mm diaphragm diameter.

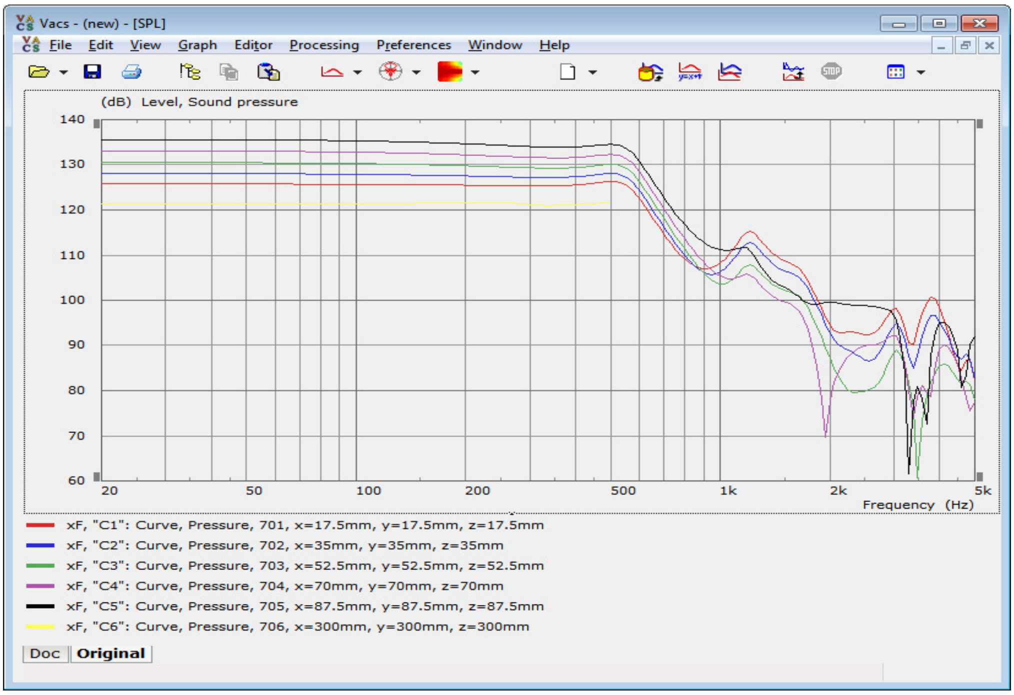
For the purposes of this report we will present measurements on a SEAS H1207 – this has a stiff, light aluminium cone and low loss rubber surround.

(1) A theoretical Boundary Element Model was built to test the underlying theory.
(2) Plots of the Sound Pressure Level versus Frequency are to be produced
(3) Plots of the Sound Pressure Field at Various Frequencies are to be produced.
(4) Measurements of a SEAS H1207 Loudspeaker on an IEC Baffle as a ground plane
(5) Measurements are to be conducted of a SEAS H1207 Loudspeaker using a Medium Tetrahedral Test Chamber
(6) The Acoustic Measurements are to be made HOLMImpulse software, the internal and external Microphone being an NTi M2010 ½" type.
(7) Draw appropriate conclusions from the theory and measurements.
(8) Further measurements of another TTC350 fitted with a Behringer C2 microphone.

Theoretical Simulations on a Tetrahedral Test Chamber:

BEM Model:

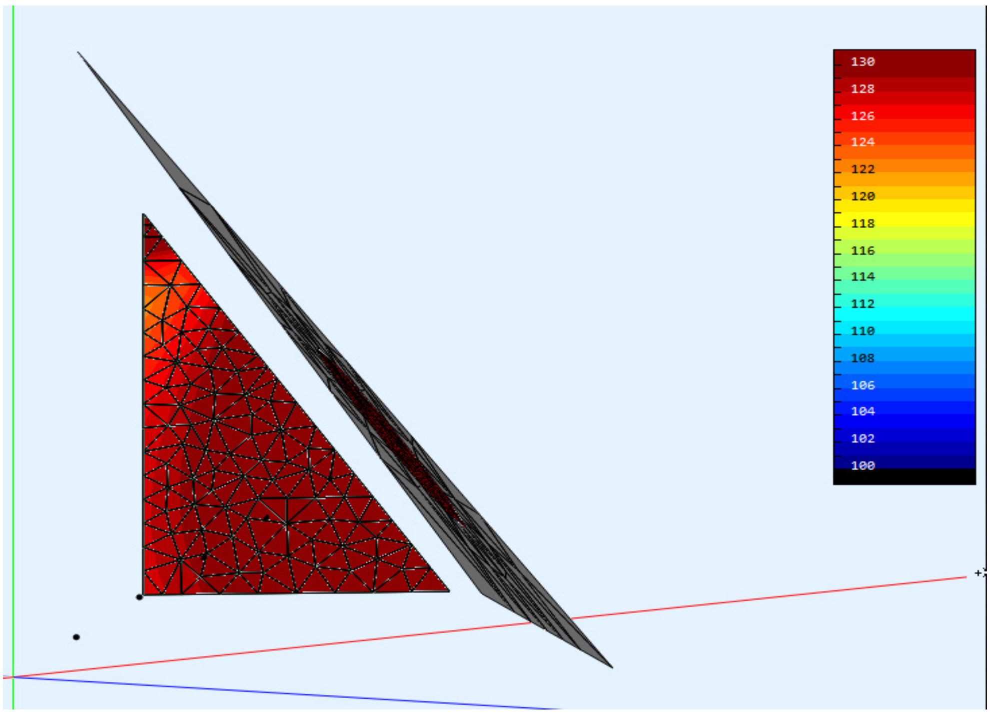
A Boundary Element Model was made using ABEC 3 http://randteam.de



This clearly shows that below 500Hz the system works as a Pressure Environment, above this frequency there are some modes, which are effectively controlled by the Acoustic Absorption

Field Plot at 300Hz from ABEC

Simulated on the inside tetrahedral on the microphone plane

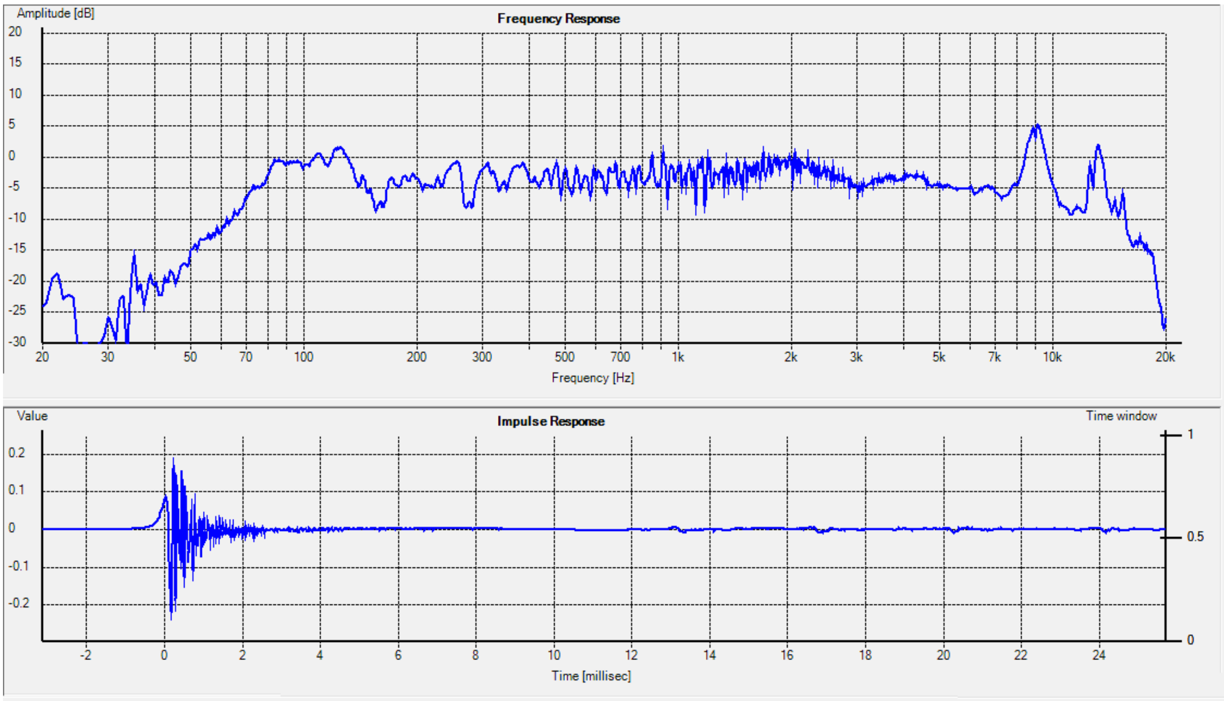


Field Plot at 300Hz shows that all regions are at nearly the same SPL

Conventional Measurements:

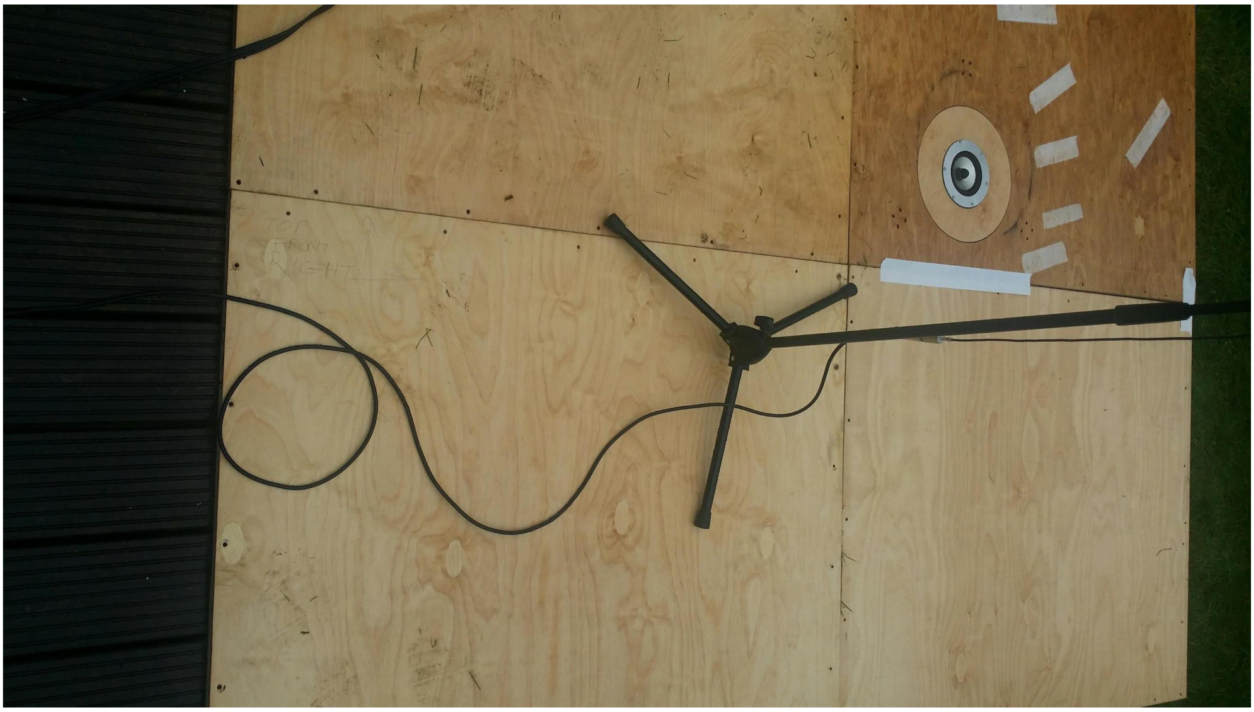
These measurements were made on a SEAS H1207 kindly supplied by SEAS of Norway.
A full size IEC Baffle was laid out as a ground plane with a ½" Microphone (not shown) was vertically suspended directly above the loudspeaker at approximately 1m.

IEC Baffle as Ground Plane Measurements:

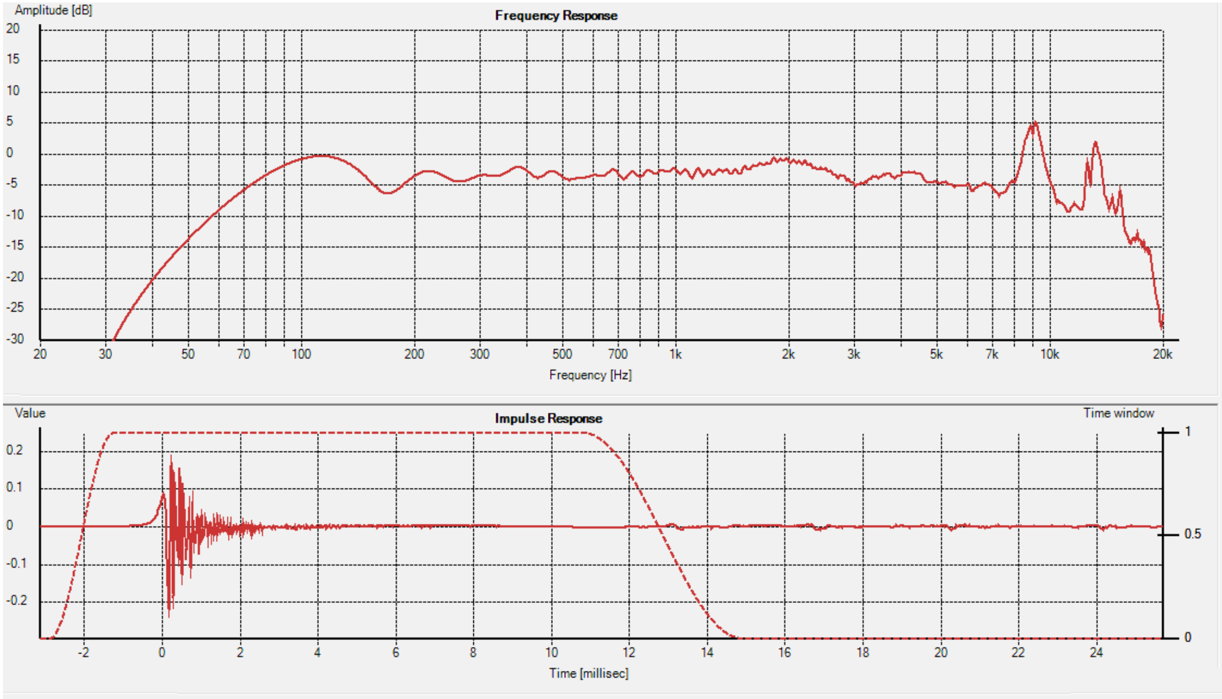


As can clearly be seen there are significant reflections however these mainly start after 10 to 12mS, the major impulse reflection starting at around 13mS the low frequencies being unreliable.

Photo (from above) of a large IEC baffle laid out as a ground plane



IEC Baffle windowing data at 12mS

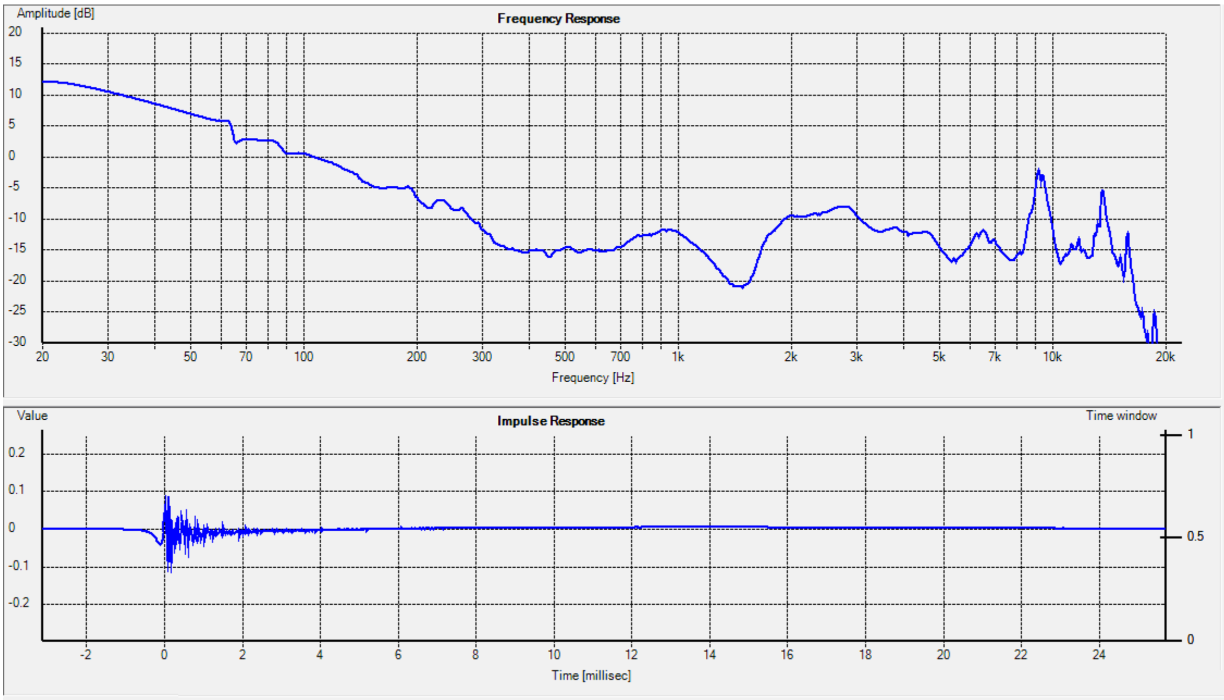


This clearly removes the majority of the reflection artefacts especially above 500Hz, where this result can justifiably be considered as anechoic. In theory a 12mS Window should be reasonably accurate below 160Hz and is often considered as safe down to 80Hz!

Tetrahedral Measurements

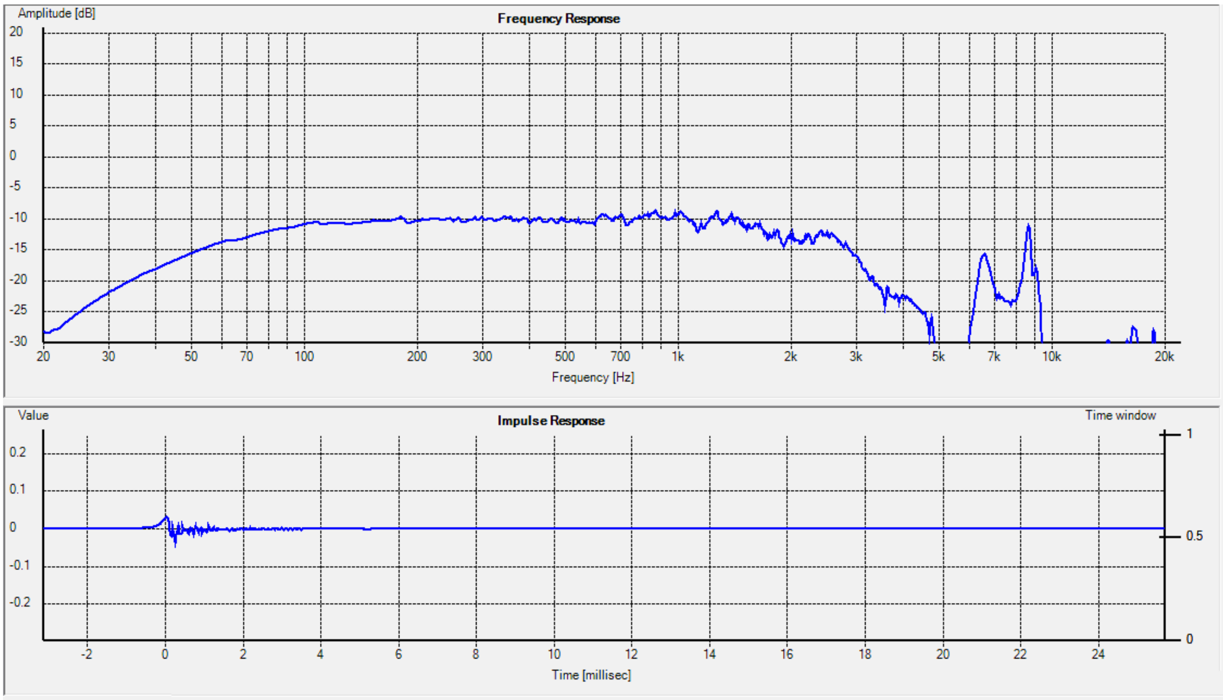
The same loudspeaker was then measured in a model TTC750 chamber. The microphone is at 316mm from the internal face of the TTC.

Internal SPL



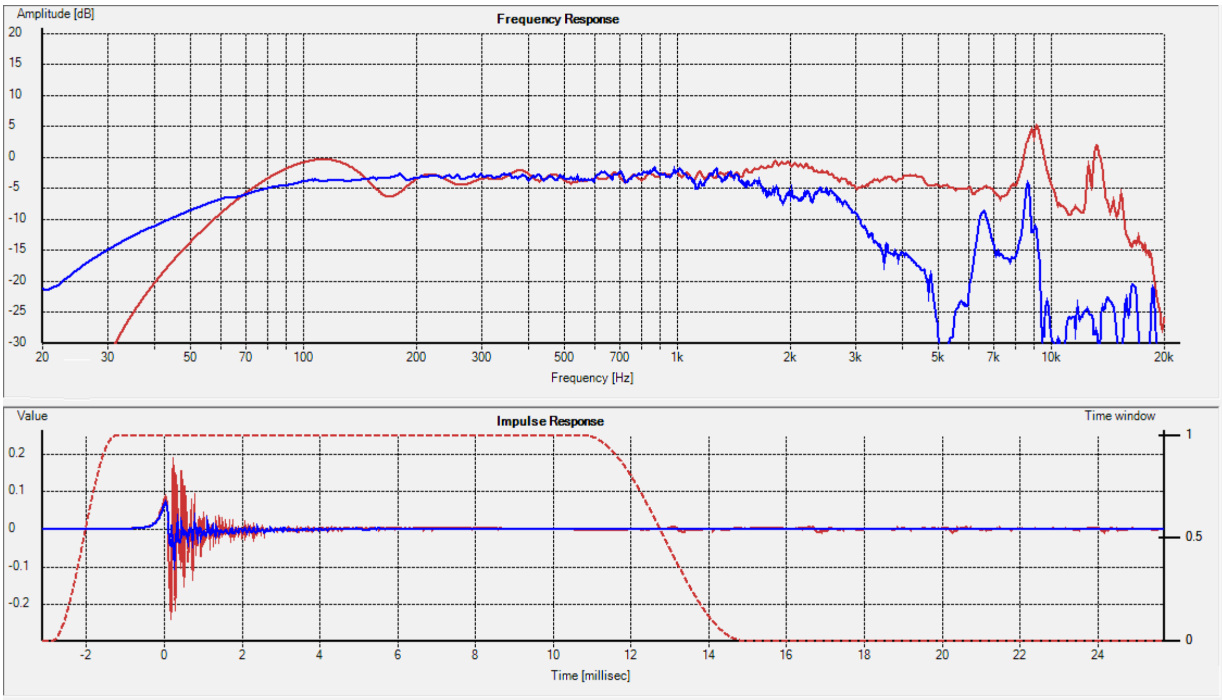
As can clearly be seen there is a considerable rise in energy at low frequencies, this can also be seen in the lower time trace. However the response from 2 kHz upward looks fairly good.

External SPL



Most loudspeaker drivers are predominantly pistonic at lower frequencies the front of a loudspeaker diaphragm is 180 degrees out of phase with the rear of the diaphragm. Where this applies. We can use this fact by measuring the diaphragm output in the *VERY* near field (5 to 10mm from diaphragm) as is shown above. Here the response follows very closely a simulated response at least up to approximately 1700Hz which corresponds to the theoretical pistonic range approximating to the depth of cone 10mm and diameter of around 100mm.

Overlay External SPL with Windowed Data

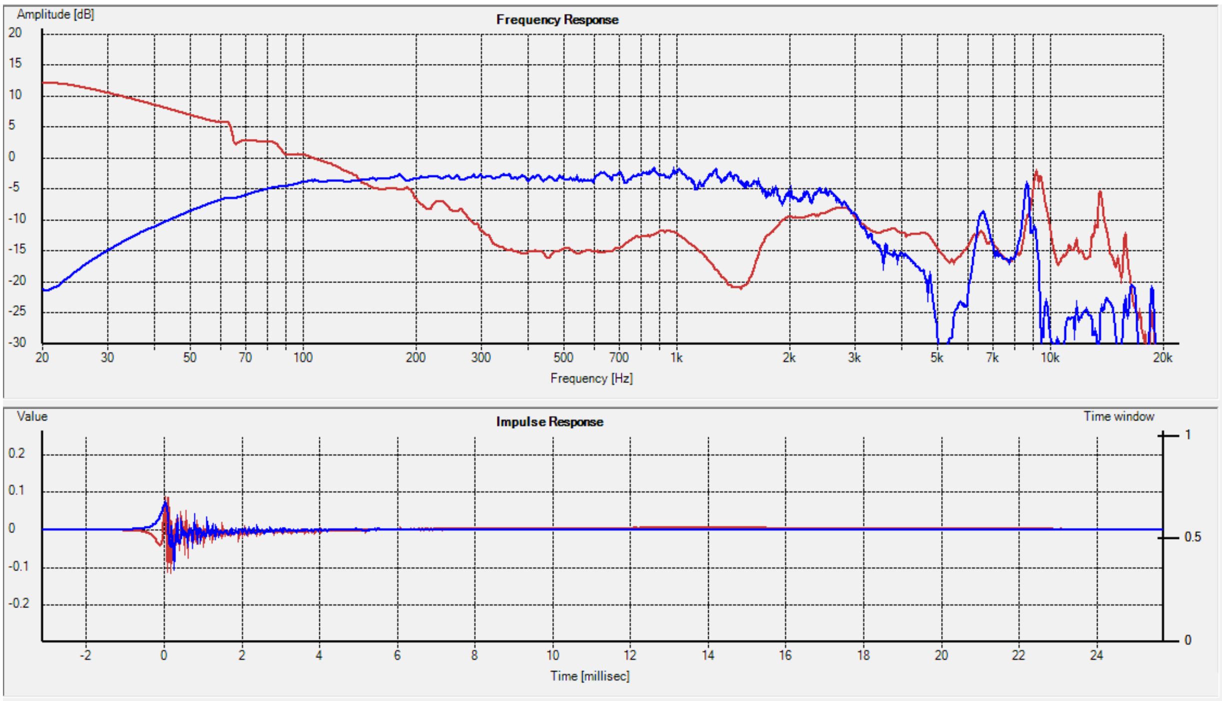


Here we can clearly see the close correspondence between these two data sets, it also show's the low frequency errors, from windowing, diffraction from the IEC Baffle edges and cancellation.

From the work of Richard Small[1] and Don Keele[2], we can use the low frequency response in the near field to accurately predict the far field response of a loudspeaker in a given enclosure.
Thus by combining the work of these we can accurately predict a low frequency correction curve.

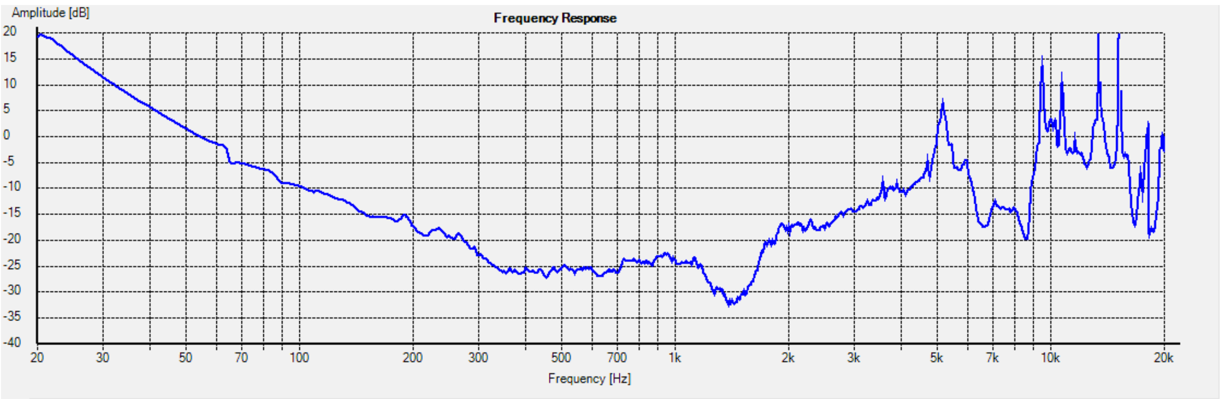
We will therefore proceed to generate an inverse correction curve by subtracting the External Curve from the Internal Curve over this frequency range at least. The process is shown next…

Overlay of Internal and External Curves



We will simply take the difference between these two curves the exact details differ between various measurement systems. This can be simply achieved in a spreadsheet by dividing these two curves. In practice this means subtracting the dB levels at each frequency in turn. Note Phase is NOT required.

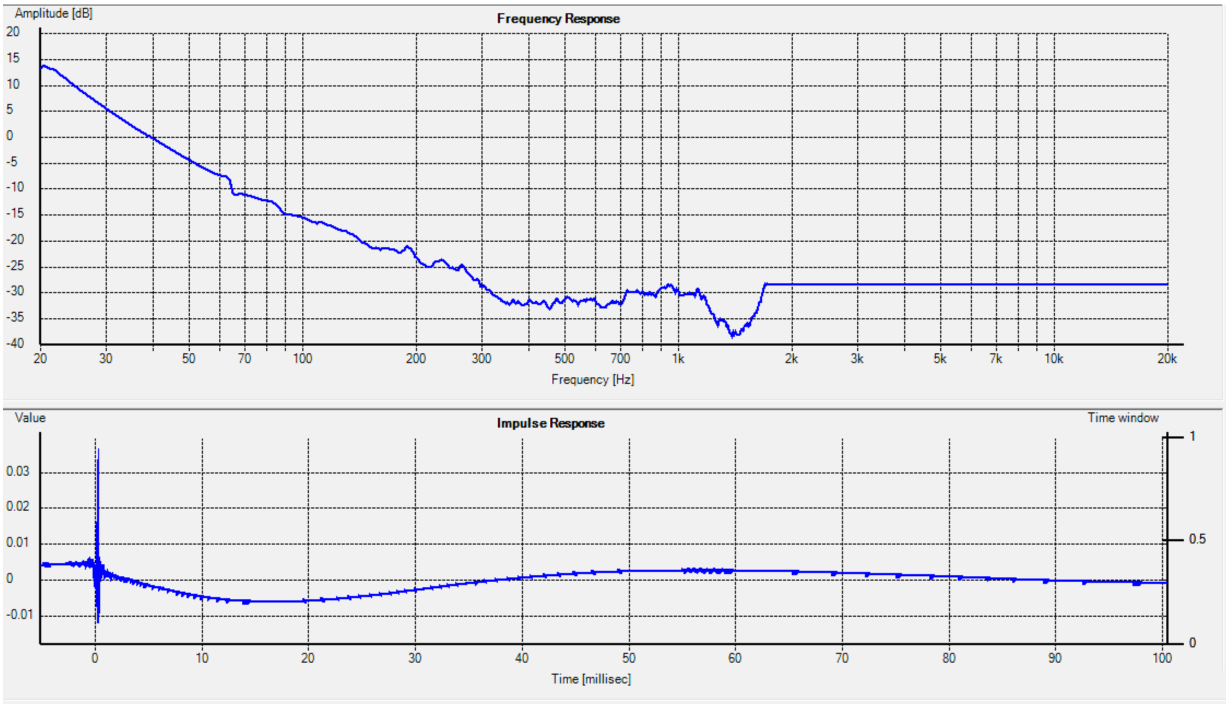
Rough Equalisation Curve



The resulting correction curve is reasonably clean at low frequencies but it is showing a considerable 45dB rise at low frequencies, however it is clearly completely inaccurate at high frequencies.

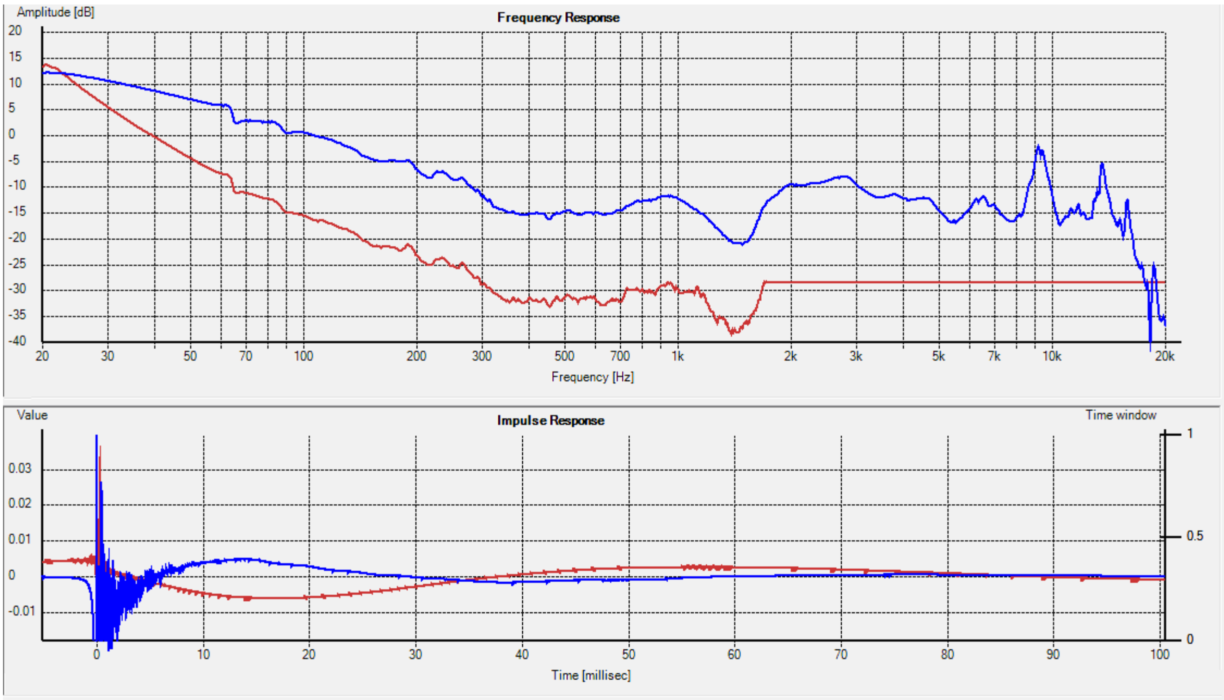
We deal with this by initially setting the levels above say 1700Hz to be equal this may also be used as the 0dB reference level, again the exact method will depend upon the measurement system used.

Final Correction Curve



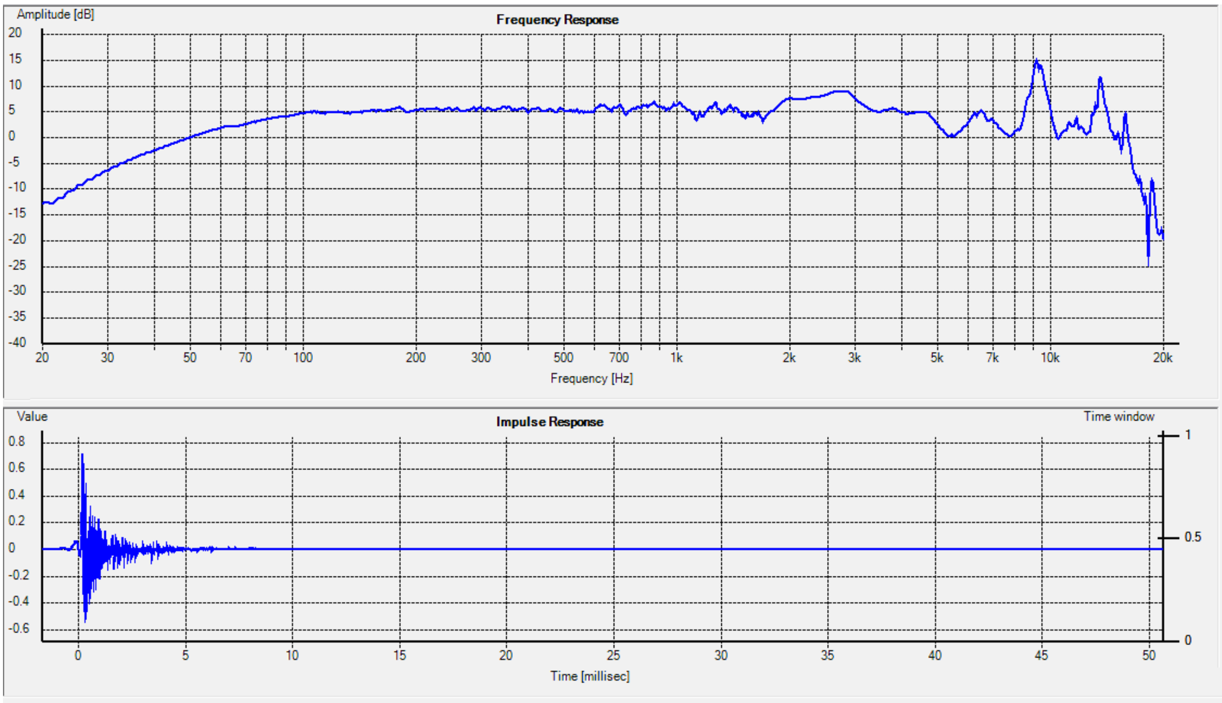
This then becomes the final correction or equalisation curve this can be directly applied to the Internal SPL curve either as a part of a Microphone or other correction or as a post process.

Overlay Internal and Correction Curve



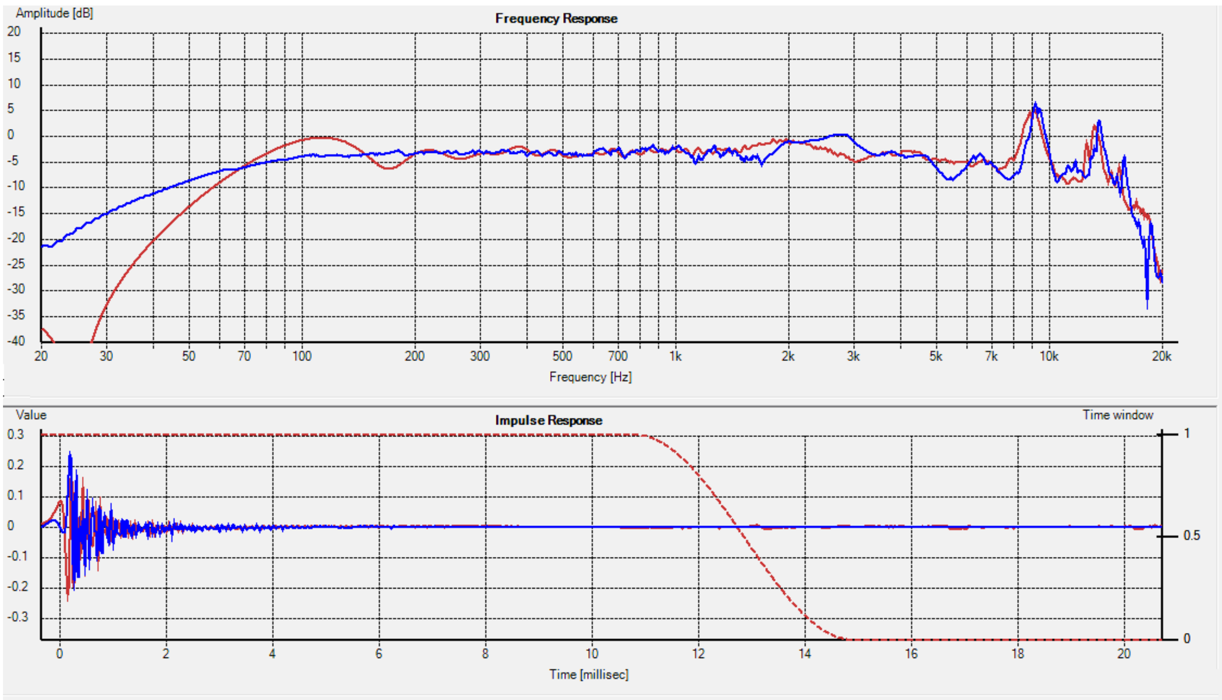
We then get the result: -

Final Result



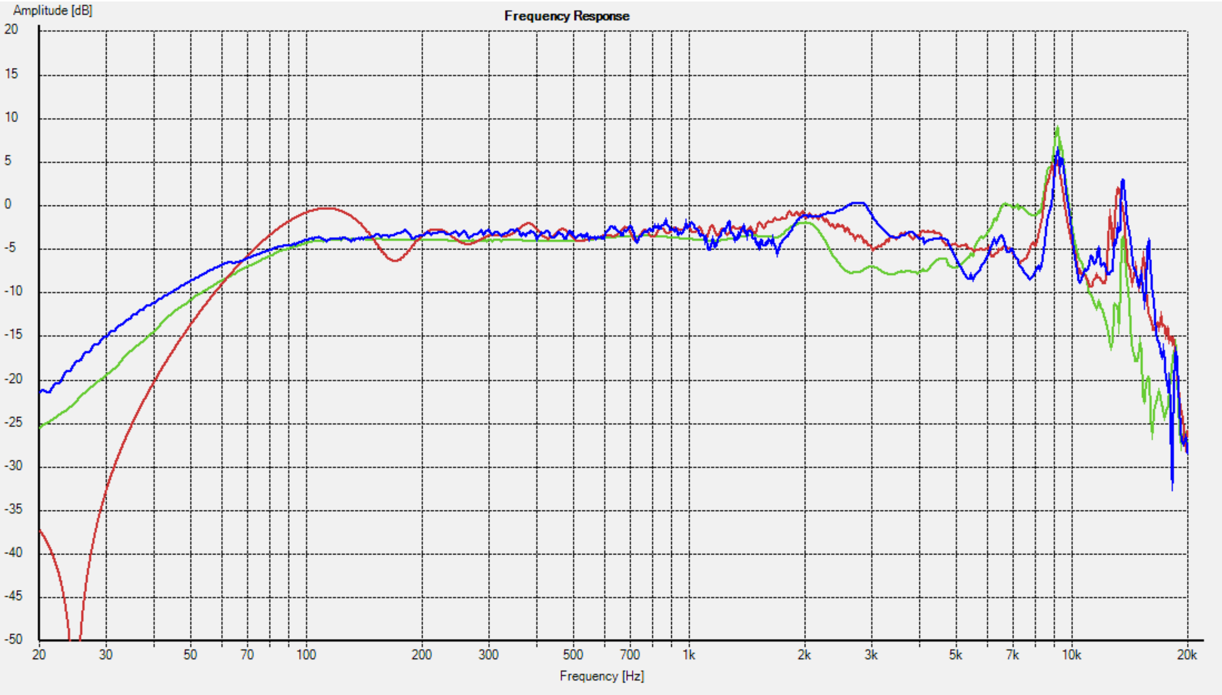
As can clearly be seen the low frequency rise has been completely eliminated, this is confirmed by the lower time trace which now tails off very rapidly, indicating at least theoretically that we can use this technique to measure accurately to very low frequencies.

Overlay of Windowed IEC vs. TTC750 Measurement



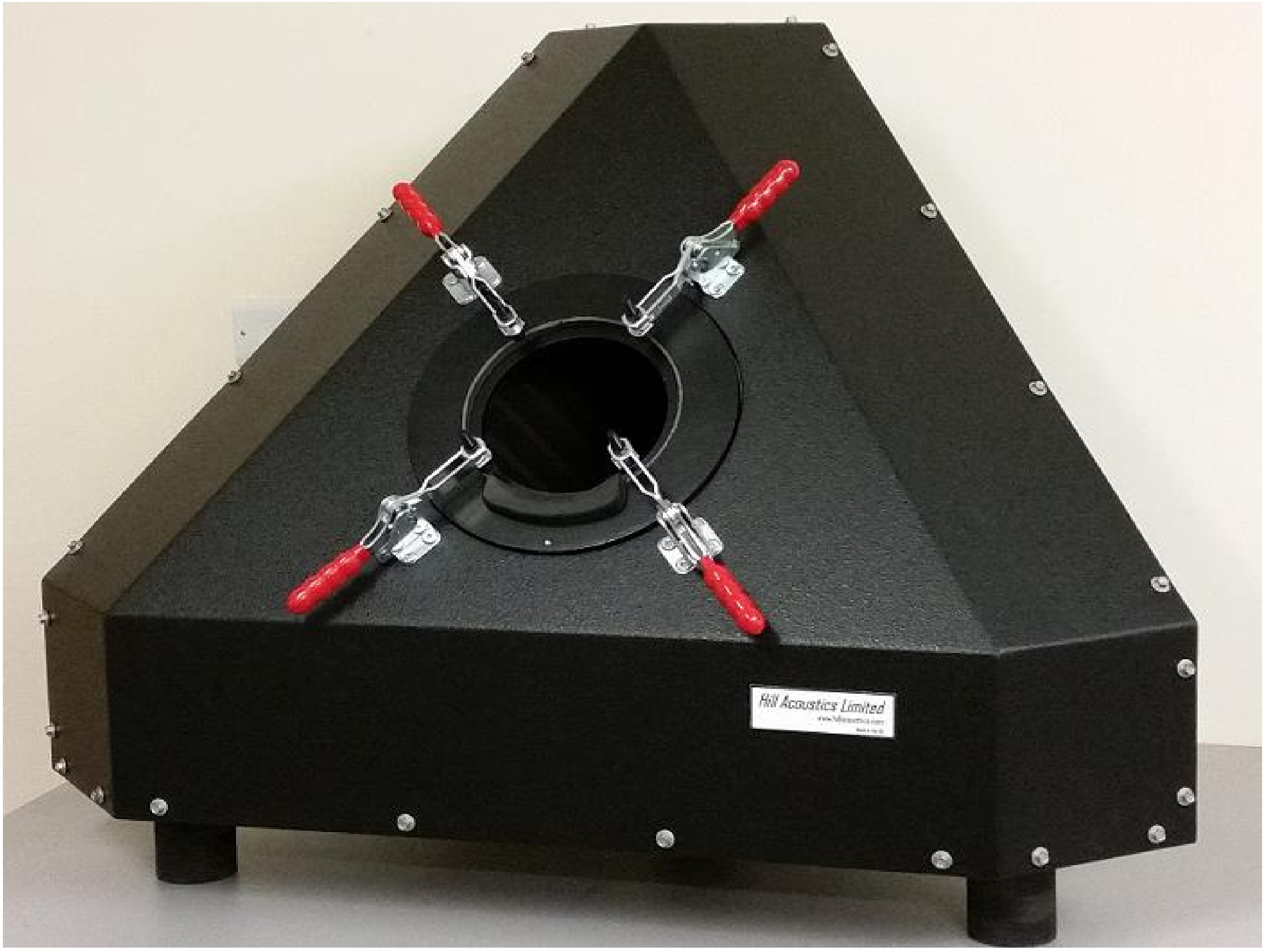
Clearly the low frequency response is accurate however the high frequency performance is also quite reasonably reliable within 5dB of the windowed response even without further correction which could be applied if higher accuracy were to be desired

Overlay of Windowed IEC vs. TTC350 & TTC750 Measurements



IEC Baffle = Brown, TTC350 = Green, TTC750=Blue, Normalised Data using the same H1207 driver

Example of a TTC750 Tetrahedral Test Chamber



Example of a TTC350 Tetrahedral Test Chamber

Comparison and discussion:

Comparing the final correct response curve with the IEC response curve shows there is a remarkably good correlation with all critical features of the loudspeakers frequency response captured by the TTC's.

The rigidly defined measurement geometry together with interchangeable sub baffles of the TTC's ensures rapid, accurate repeatable measurements time and time again.

It can be easily calibrated and either a generic response correction used or a specific correction produced for when the highest accuracy (e.g. driver matching).

Due to the comparatively small sizes of the various TTC s it is possible to use them in situations where a full anechoic and IEC baffle could never be used include the designers own bench, the QA/QC lab, the end of the production line, and the goods received test station. Used throughout the supplier chain results would be directly comparable, directly eliminating major communication problems.

Conclusion:

The measurements from the TTC correlate very well with those measured by an IEC baffle, however they are of much higher resolution and do not show the rough responses of IEC Baffle Measurements.

From the both a theoretical point of view and from actual physical measurements – the Tetrahedral Test Chamber is capable of giving accurate, repeatable measurements within a relatively small size.

It can be easily calibrated and either a generic response correction used or a specific correction produced for when the highest accuracy is required very simply using the steps in this report. Such a Chamber would dramatically simplify setting measurement tolerances on loudspeakers by eliminating practically all of the modal effects of our current loudspeaker test enclosures.

Recommendation(s):

This report has proven the capability of the Tetrahedral Test Chamber to make substantial improvement in our acoustic loudspeaker measurements. We should embrace this technology throughout our organisations.

Use of several of the Tetrahedral Test Chambers throughout the entire supply chain would give our companies unprecedented accuracy and consistency of acoustic measurements, this will lead to lower costs and higher standard products by eliminating the current situation of differing acoustic measurement set-ups at different stages and replacing them with a single known set-up capable of the highest standard, allowing us to make accurate comparative measurements throughout the supply chain.

By using these at all stages of production we will eliminate the unknown variables that are purely due to the different measurement techniques currently in use.

References:

1. Simplified Measurements at Low Frequencies, Richard.H.Small, January and February 1972, published by the Audio Engineering Society
2. Low-Frequency Loudspeaker Assessment by Near Field Sound-Pressure Measurement. D.B.Keele, Presented May 15th, 1973 at the 45th Convention of the Audio Engineering Society, Los Angeles.
3. Measuring the True Acoustical Response of Loudspeakers, Alan S Phillips, SAE Technical Paper 2004-01-1694, 2004, doi:10.4271/2004-01- 1694. http://papers.sae.org/2004-01-1694/
4. HOLMImpulse software http://www.holmacoustics.com/holmimpulse.php
5. ABEC 3 and VACS software from http://www.randteam.de
6. Consistently Stable Loudspeaker Measurements Using a Tetrahedral Enclosure – engineering brief, Geoff Hill, Presented 16th October 2013 at the 135th Convention of the Audio Engineering Society in New York. http://www.aes.org/e-lib/browse.cfm?elib=16958
7. Comparative Results between Loudspeaker Measurements Using a Tetrahedral Enclosure and Other Methods – engineering brief, Geoff Hill, Presented on 25th April 2014 at the 136th Convention of the Audio Engineering Society in Berlin. http://www.aes.org/e-lib/browse.cfm?elib=17152