Audio Engineering Society

Convention e-Brief

Presented at the 135th Convention
2013 October 17–20 New York, USA

Consistently Stable Loudspeaker Measurements using a Tetrahedral Enclosure

Geoff Hill[1]

[1] *Hill Acoustics Limited, Leigh on Sea, Essex, SS9 1LA, United Kingdom*
geoff@hillacoustics.com

ABSTRACT

A major problem for the loudspeaker and transducer industries throughout the world is an inability to rely upon measurements routinely exchanged between suppliers and customers.
A system is proposed that offers a unique and stable test environment giving an opportunity to standardize and compare results between measurement sites. It works by having an enclosure shape that eliminates standing-waves and having acoustic foam to eliminate any remaining high frequencies. It then rigidly defines the measurement geometry together with interchangeable sub baffles, ensuring rapid and accurate change over and repeatable measurements. With several in use in the design, production and customer chain results will be comparable unit to unit throughout the world to an as yet unprecedented degree.

1. BACKGROUND

Throughout the world an enormous amount of time goes into measuring loudspeakers, only for the customer to do the same measurements again as they cannot trust the data received from the suppliers.

This is not due to our equipment as hardware, software and microphones have long ceased to be significant sources of errors.

Rather I believe that it is the lack of a consistent environment and measurement geometry that is the real reason for the inconsistencies that we currently see.

There are standards for making loudspeaker measurements notably from the IEC and JIS. Unfortunately both of these standards are relatively old and do not really suit the ways modern loudspeaker drivers are produced or tested in today's world. Many of the issues are summarised by Alan S Phillips' paper: 'Measuring the True Acoustical Response of Loudspeakers' (1).

2. ANECHOIC CHAMBER—MEASUREMENTS

During my career I have designed and specified many anechoic chambers both alone and with help from others. One problem has come up time and time again—inconsistency due to set-up variations. This is odd because pretty well all of the calibration routines and procedures assume that it's the equipment that varies. This may have been the case in the past but today it is unlikely as modern equipment is far more stable and consistent than it has ever been.

In my experience the problem really comes down to the human factors. If sufficient care is taken and you use an appropriate anechoic chamber with a correctly set-up IEC baffle or JIS test box you can get reliable measurements that can be reproduced by another equally well-trained, disciplined and equipped individual elsewhere in the world. So we need to ask ourselves a different question: 'What is it about these standards that means in practice the results from them are so variable as in many cases to be useless?'

There are a few reasons—amongst them are the following:

- Measurements using both methods need to be made in an anechoic environment
- Anechoic chambers vary wildly in their size and performance
- Most anechoic chambers are designed to minimise external noise influences [1]
- It is essential that the baffle or test box together with microphone be correctly set up but there is little if any guidance on how to do this
- The loudspeaker to be measured must be appropriately mounted; again, there is little real guidance
- It is essential that the acoustic environment around the baffle or test box and microphone be completely clear of items that can reflect sound, but it's not unknown for chambers to be cluttered up as they are often used as large storage spaces
- The anechoic chamber must be designed so that nothing interferes with the measurements, though they often have floppy mesh floors that are unstable or protruding beams
- The microphone should be set up so that measurements are made in the far field of the loudspeaker being measured but then the results are to be referred back to the equivalent measurement made at 1m

From the above there are so many possibilities it is no wonder that we cannot achieve consistently reliable measurements at different locations.

[1]Not necessarily of the highest importance when measuring a loudspeaker at 70 to 100dB SPL

3. MOUNTING A LOUDSPEAKER

In order to make consistent measurements the best way is to use a series of removable and interchangeable standardised measurement 'sub baffles', one for each type of loudspeaker drive unit to be measured: The exact design of these is changed to mate accurately to the loudspeaker driver being tested without causing any damage .

These sub baffles are then mounted into the main measurement baffle. This could be an IEC baffle, a 2π baffle built into one wall of an anechoic chamber, a JIS test box or the proposed structure.

Focussing on a sub baffle its main requirements are:

- To provide a simple and reliable method of changing between drivers
- To provide a precisely repeatable and secure mounting for the driver
- To change the acoustical loading of the driver as little as possible
- To accommodate a large range of physical sizes of drive units

1. The driver being clamped from the rear into the sub baffle and the sub baffle being clamped from the rear into the main baffle.
2. The sub baffle which mounts the drive unit *must not* have a gap of more than 1mm ($\pm$0.1mm) between the drivers mounting face and the face of the sub baffle.
3. The face of the sub baffle *must* be flat to the face of the main baffle ($\pm$0.1mm).
4. The face of the main baffle *must* be flat and acoustically reflective

See drawing below:

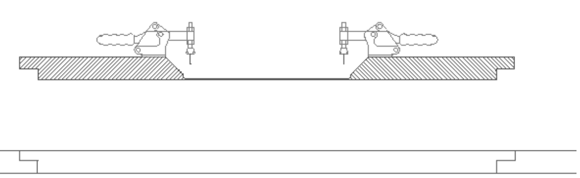

Figure 1. Measurement baffle

4. WHAT IS THE SIMPLEST POSSIBLE LOUDSPEAKER TEST ENVIRONMENT?

When I asked this question it then struck me that many of the most consistently reliable measurements that I had made in the past had often used a microphone in a corner pointing toward the loudspeaker.

So how could this be applied in practice? The proposed design uses a tetrahedral enclosure. [2] Very closely related is a tetrahedron constructed of three identical right angle triangles and one equilateral triangle. This gives more internal volume and is easily built into the corner of a room. We could in principle use a corner of a room with a single triangular baffle and sub-baffle.

This design has the benefit of maximising the baffle area, in a production version of this concept the corners are not very useful so they have been squared off and filled with acoustic absorption [3]. A microphone coming out from the corner at a 45° angle and facing the flat internal baffle at a fixed distance completes the overall structure.

A picture of a pre-production version is shown next:

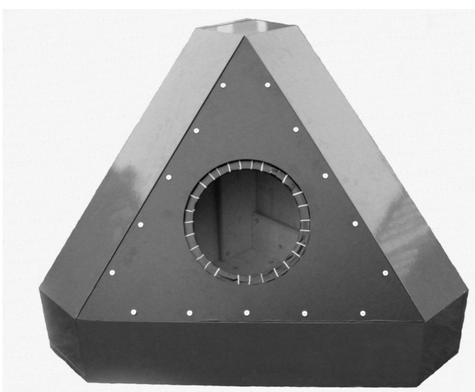

Figure 2. Tetrahedral enclosure

How does this benefit us? Quite simply we now have both a defined acoustic environment and a defined mechanical geometry, removing many of the potential set-up problems that beset our current standards. Because the design is much simpler and smaller it is much less likely to be tampered with and should retain its mechanical and acoustical integrity for much longer with needing continual upkeep.

The next steps are (i) defining the mechanical aspects of the tetrahedral enclosure and the mating ‘sub baffle(s)’, (ii) deciding what size(s) the overall design should be.

Obviously a design suitable for a micro-speaker and a design for a 30 inch subwoofer loudspeaker drive unit will have very different requirements. Initially I propose planning for four sizes:

1. Micro version for ear buds etc.—Design TBA
2. Small version—incorporating a 150mm diameter baffle size that will handle up to a 6½″ or 7″ driver without problems. This should fit within a 0.4m × 0.4m footprint making suitable for high volume desktop operations.
3. Standard version—incorporating a 300mm diameter baffle size that will handle up to 10″ or maybe 12″ drivers without problems. This could then fit within a 0.9m × 0.9m footprint [4] and would have approximately 360 litres of internal volume.
4. Larger versions—incorporating a 600mm or greater diameter baffle size that will handle 15″ Drivers or greater. These would need a 1.5m × 1.5m footprint or greater, depending upon the driver size.

4.1. BEM Modelling

A simplified model was built in ABEC 3 from RandTEAM this used a value of 0.99 WallImpedance (damping) to simulate the acoustical reflection at the walls of a ‘perfect tetrahedral’; the simulation shows the predicted acoustic response at various virtual microphone positions from a acoustically perfectly flat source.

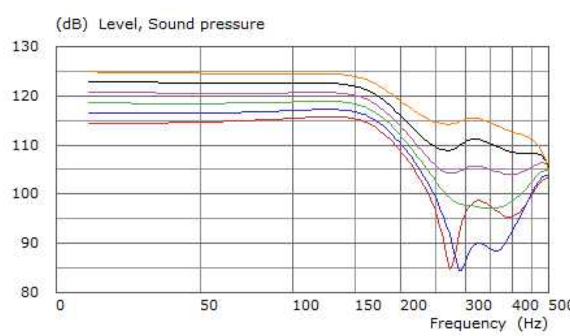

Figure 3. Frequency response

Looking at the curves there is a rising (pressure) response below 150Hz, and generally smooth responses tending

[2] A regular tetrahedron being the simplest 3D shape with just four equilateral triangles

[3] This external shape is covered by EU Registered Design number 002292532

[4] Ensuring it fits on a standard 1m × 1.2m pallet

towards a flat response at the preferred microphone positions which are easily corrected.

4.2. Measurements

These initial measurements have been produced with generic low cost (albeit modern) equipment:

- Uncalibrated/corrected Behringher ECM 8000 microphone
- Rowland UA-25 EX USB sound card
- HOLMImpulse measurement software

The measurements are shown were taken at the AES Finland Conference between the 22 and 24 August 2013 of a Peerless 830656 Bass-Mid driver; the Red curve on the 22 August and the Blue on the 24 August after many the system had been opened up many times for inspection and other measurements of different Bass drivers and tweeters conducted.

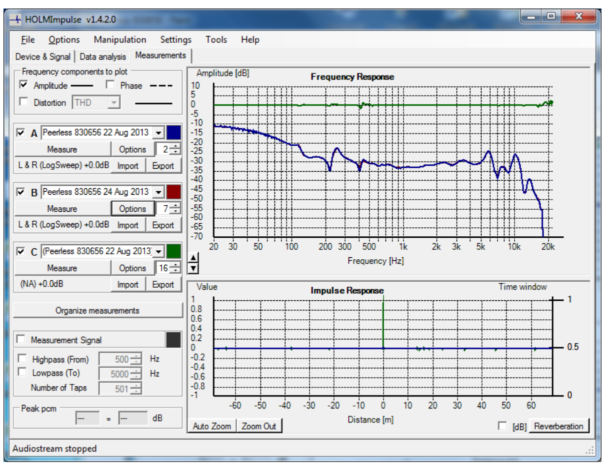

Figure 4. Peerless driver

Although it is difficult to see here (and even when reproduced at full scale), there are two completely separate measurements here—these are a red and a blue trace—to make it clear, the green trace is a difference curve of the same driver but two full days apart, demonstrating excellent measurement stability.

4.3. Calibration Methodology

We know from actual measurements and simulations that the pressure is equal everywhere inside the enclosure it is not flat with respect to frequency. Richard Small used this technique in his paper 'Simplified Loudspeaker Measurements at Low Frequencies' (2) over 40 years ago to measure low frequencies without an anechoic environment. With modern equipment and software we can do better.

So to make accurate and reliable measurements we can derive a basic correction curve by measuring the external nearfield response of a drive unit and subtracting this from the measured internal (pressure response) inside a tetrahedral test system and apply this as a microphone correction curve.

5. CONCLUSION(S)

A new method for measuring the Acoustic Performance of a Loudspeaker Driver or Transducer has been described based upon a Tetrahedral shaped enclosure with fixed Geometry and interchangable baffles. This allows rapid changeover between differing measurements together with very high consistency and measurement stability.

The next stage is to get this system adopted more widely so that we can verify it throughout the the supply chain.

6. ACKNOWLEDGMENTS

Thanks to Phil Knight for many theoretical discussions, Alan Slaughter and the production team for valuable suggestions, and to all at the AES 51st Conference at Helsinki, Finland for further feedback.

References

[1] Alan S. Phillips, 'Measuring the True Acoustical Response of Loudspeakers', *SAE Technical Paper*, **2004-01-1694** (2004).

[2] Richard Small, 'Simplified Loudspeaker Measurements at Low Frequencies', *JAES*, **vol 20** (issue 1), pp 28–pp 33, (1972).

[3] HOLMImpulse [Online]
www.holmacoustics.com/holmimpulse.php
[Retrieved 13 October 2013].

[4] ABEC 3 & Vacs [Online]
www.randteam.de
[Retrieved 13 October 2013].