Measuring absorption below 100Hz with a particle velocity-pressure sensor

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ABSTRACT

Absorption is difficult quantity to measure. The standards based on reverberation chamber measurements are limited to those above 100 Hz. Those based on commercially available impedance tubes are limited to 63 Hz and above. The Microflown impedance gun offers a newer approach to the measurement of absorption coefficients, but is limited to 300-8000 Hz in its commercial form. An extension to the commercial instrumentation to lower the operational range to 40 Hz is proposed. Measurements have been undertaken of dissipative type absorbers and panel absorbers to determine if this method can be used in the 40-100 Hz range. Results are reported and discussed along with the uncertainty in the measurement.

Keywords: Sound, Absorption, Measurement, Intensity, Low Frequency

1. INTRODUCTION

Since Sabine's foundational work in acoustics, knowledge of the sound absorbing characteristics of construction materials has been of fundamental importance for Acousticians aiming to predict the nature of a planned space, or treat an existing one. These characteristics are commonly expressed using absorption coefficient, or α. Bass, the lowest frequency range, although one that we are relatively insensitive to, is still the foundation of musical experience. Perception in this area is complex as, at vibration of the surface of the skin and body parts can augment the normal function of the ear in contributing to this unique part of musical sensation (1). Especially in popular music, bass instruments define the pulse of the music and provide a temporal structure for dancing (2).

In rooms for classical music performance, Barron notes that bass rise, that is to say a reverberation time increase as frequency lowers from around 500Hz, has been seen as desirable or at least tolerated in auditoria, especially in the USA. He notes that European consultants prefer clearer bass and aim for a flat reverberation response (3). More recent work shows a trend toward the pursuit of clearer low frequency response in music rooms. Fuchs, however points out that early reflections at low frequencies interfere detrimentally with direct sound, causing bass lines to be obscured. He calls for new strategies for bass absorption and the striving for bass drop in music rooms as a design goal (4). Also in Europe, Adelman-Larsen's analysis of large scale amplified music venues have realized that especially in that context, control of low frequency reverberation is a must if any kind of clarity is to be achieved (5). In addition to traditional approaches, new technologies are being developed to serve this need for low frequency control. Adelman-Larsen's company manufactures large-scale inflatable treatments for very large venues, which profess good low frequency absorption performance, and adsorbing materials such as activated carbon also appear to have excellent low frequency properties (6).

But how to test their performance? Few standardised techniques work well below 125Hz, leaving the lowest two and a half octaves unmeasured.

This report investigates the issues and problems associated with accurate low frequency measurement. It also details investigations into the experimental conversion of the Microflown Impedance Gun, a piece of equipment designed for measuring mid and high frequency absorption, for use in determining low frequency absorption coefficients. This was undertaken more to

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investigate the issues and problems associated with such measurements, rather than to devise a practical measurement setup. Results are compared to existing standard measurement procedures. The suitability of these standards and the Microflown's suitability as an investigative tool in this field is assessed.

2. THE IMPEDANCE GUN

The hot-wire anemometer was proposed in 1916 by L V King for fluid flow measurement. It was intended to address shortcomings of existing pitot tube methods, which were impractical for small pipes and slower moving flows. In his device, a drop in temperature in a heated wire is caused by the cooling effect of fluid flow; this heat loss increases with fluid velocity. By measuring either this heat loss or the extra current required to maintain the wire's temperature, fluid velocity can be calculated (7). This method has become a standard for measuring low velocity and turbulent fluid flows in industry.

There had been attempts as early as 1955 to apply this method to measurement of acoustic particle velocity (8). but a practical acoustic velocity sensor using this principle did not arrive until 1994 in the form of the Microflown sensor, a micro-machined velocity sensor employing two very fine heated wires, facilitating flow direction to be determined as well as flow rate. In the commercial product, this velocity sensor is combined with a near-coincident pressure microphone. Together they comprise a high quality and flexible P-U probe for intensity based measurements.

The Impedance Gun setup comprises a single Microflown P-U sensor mounted in a chassis 26cm away from a small spherical loudspeaker. This arrangement is calibrated and mathematical models for the resulting propagation are incorporated into propriety software, which runs on a PC.

The setup is intended to be a portable in-situ absorption measurement system which can be used almost anywhere to determine the absorption coefficients of building materials.

2.1 Operation

Two or more measurements are taken for each location of interest. The first is a measurement with infinite termination, that is, the gun is pointed away from all reflective surfaces. Thusly the loudspeaker output and general measurement environment are characterised. Subsequently, the gun is oriented such that the sensor is extremely close (5mm) to the sample to be tested. In this way the (known) incident and reflected signals are characterised. Post processing is applied to smooth the resulting data to minimise effects of parasitic reflections. Corrections are applied for propagation based on three models (see below). Although the impedance gun is highly directional and the measurement position are is very small, Microflown recommends a sample size of at least 300x300mm (9).

2.2 Theory

Three propagation models, of successive complexity, are used to correct for sound source type and derive impedance and hence absorption coefficient.

The Plane Wave Approximation Method is simplest in that it assumes that the source produces a plane wave, which upon striking the sample gives rise to a plane reflection, which is changed, in magnitude and phase by the nature of the material. The Mirror Source Method adds the notion of the reflection being a second, mirror source to the above equation. It requires exact determination of source-sample and sensor-sample distances.

The Q-Term Method is a highly mathematical method relying on an exact description of the sound field above an infinite locally reactive plane. It does not assume plane propagation but relies on precise integration of pressure and velocity. However, the method does not return impedance results below 125Hz. And since the impedance gun as sold is useful only down to 300Hz then this limitation of the software might be understandable. In addition the implementation of this (and the other methods) are calibrated for the known small loudspeaker source and non necessarily valid for the Subwoofer (10) (9).

3. EXPERIMENT

Experiments were undertaken with the impedance gun retrofitted with a JBL subwoofer as a source. This is of course in contravention of the conditions of operation, as the stock source is calibrated and correction models assume it's use, however this was felt to be an interesting initial exercise which would shed light on the problems of low frequency measurement. Initial feasibility tests will be outlined, as will measurements of specially constructed low frequency membrane absorbers.

3.1 Test Schedule

Two sets of test materials were used. First, an open-cell foam panel was tested as a simple porous target material for the Microflown + Subwoofer setup. This was performed to confirm that the new arrangement's functionality and to give an initial impression as to the veracity or otherwise of it's results.

The second set of tests took place on three reactive membrane absorbers designed and built specifically for this test. A test sample with absorptive performance specifically in the lower frequency range was required in order to truly test the setup. These absorbers were tested in two conditions:

Empty
Damped with 75mm Mineral Fibre

For each case, the panels were tested according to BS 354 as a reference and then with the test setup. Results will be presented in the frequency range of interest below 315Hz, approximately the lower limit of the stock impedance gun.

Figure 1: The probe mounted as close as possible to the sample surface. Note the spherical loudspeaker closest to the camera was not connected.

3.2 Experimental Setup

The majority of the Microflown apparatus was used as supplied, the only difference being the substitution of the subwoofer for the supplied loudspeaker. Most cabling was retained, however an adaptor was required to accommodate the subwoofers Speakon format input. The Microflown amplifier seemed to drive the subwoofer with no difficulty. In order to physically accommodate the subwoofer, the existing loudspeaker was not removed, but it's input disconnected, with the mount maintained, albeit at an angle of approximately 45 degrees to the face of the sample. The probe support allowed for rotation of the probe in such a way as to be oriented along the axis of the subwoofer, at normal incidence to the sample surface close to it's face. Thus the standard geometry of the impedance gun was maintained. The support was assumed to be acoustically invisible at the frequencies of interest.

The disadvantage of this arrangement was that support of the probe close to the sample surface was somewhat more difficult at this oblique angle. Secondly, the subwoofer had to be supported separately at different heights. This was a significant problem due to it's weight. With the addition of the subwoofers massive size compared to the Impedance gun's original speaker, the whole apparatus was rather unwieldy.

3.3   Proof of Concept Test

A basic test was carried out to determine whether the apparatus worked at all, and whether plausible results were obtained. These and subsequent Microflown tests were conducted outside in a courtyard adjoining the LSBU Acoustics Lab. Both test labs available (reverberation chamber and anechoic chamber) have volumes of around 200m^3 and as such had significant modal activity at frequencies of interest. The courtyard was larger, 29.8m x 9.7m and open to the air and hence such modes as were present would be fewer in number and at lower frequencies, below the range of interest. Of course testing outside opened the door to environmental factors to impact the tests. The Microflown is, as a velocity sensor, notably sensitive to wind noise, and it's operation in not recommended if wind speed is above 2ms^{-1} (higher if a windshield is used). Ironically, wind speed measurement was not available on the days of the tests, however still, dry still days were deliberately chosen for the tests and wind was considered negligible. The energy from wind noise is of course concentrated below 100Hz, i.e. frequencies of interest in this setup, so a solution would have to be devised for this to become a practical in-situ tool. [52]

3.4   Microflown + Subwoofer Test of Foam Panels

The lab retained the foam samples as target absorbers for demonstrations of ISO453 Reverberation Room measurements, so their performance was well known. Samples were arranged vertically in front of a brick wall, supported by steel stands. These were supporting the edges of the sample and were assumed small enough and far enough away to be negligible acoustically.

Pink noise was used as a sound source, with measurement duration of 4 seconds. A suitable test level was found; while it is desirable to ensure that test level is well above background noise, it is possible to clip the input of the analog to digital converter of either velocity or pressure sensor, and in this case when using the subwoofer, particle velocity level seemed higher than experienced with the stock apparatus, so a relatively conservative level had to be used.

The impedance gun was calibrated with an infinite termination. This involved pointing the gun away from any reflective surfaces (in this case upwards, towards the sky in the open courtyard) and running a measurement, the resulting pressure and velocity values being ascribable solely to the source. The software maintains this measurement as a calibration file and it is used to deduce the nature and magnitude of reflected waves and hence absorption. With the compact impedance gun as supplied, this is simple enough, but orienting probe and subwoofer such that they point at the sky was difficult and error in source-probe distance was possible and hard to quantify without more extensive tests. After calibration a series of tests were done, doubling depth of absorber each time, 75mm, 150mm, 300mm and 600mm.

3.5   Preliminary Tests with Porous Absorber

This initial test to determine basic functionality of the Microflown+Sub configuration was successful, with credible results being obtained. Figure 2 shows a result broadly in agreement with ISO 354 measurements of the same samples. Absorption coefficients themselves are somewhat less than measured in the reverberation room, however the latter is known for producing higher coefficients due to mounting effects, so one might be inclined to think that the Microflown has performed more accurately in this respect as the edge of the sample is well away from the measurement location. One other thing to note, of course, is that the Microflown's result is from a single measurement, whereas the ISO354 result is the average of 12 measurements. There is also a notable dip around 1000Hz – this could be due to some kind of mounting effect for this particular

measurement. The foam was supported by two metal stands, which could have caused reflections, however these were completely off-axis, and we have seen the Microflown is very directional with around 50dB rejection off axis, so it is unlikely their effect is significant. It is possible there was a small air gap behind the sample which caused some resonance effect, but again this would be expected to be small.
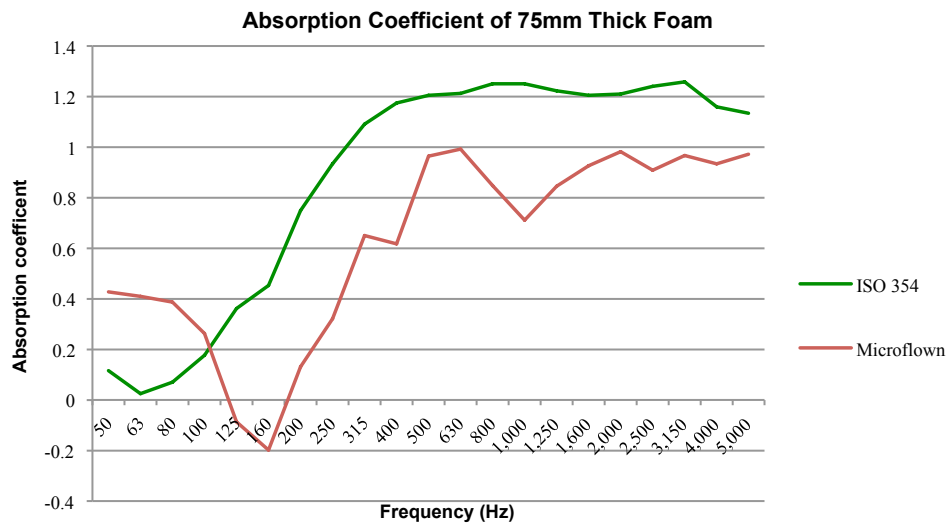

Figure 2: Absorption coefficients for 75mm thick foam measured by BS354 and by Microflown

Where the measurements do differ is in the low frequencies. There is a dip in the Microflown result around 160Hz and increased coefficient reported below 100Hz. The former is the result of two negative coefficients reported by the Microflown in the 125 and 160Hz bands. Negative coefficients are common with the impedance gun setup due to the vagaries of the calculation used to derive reflection factor.
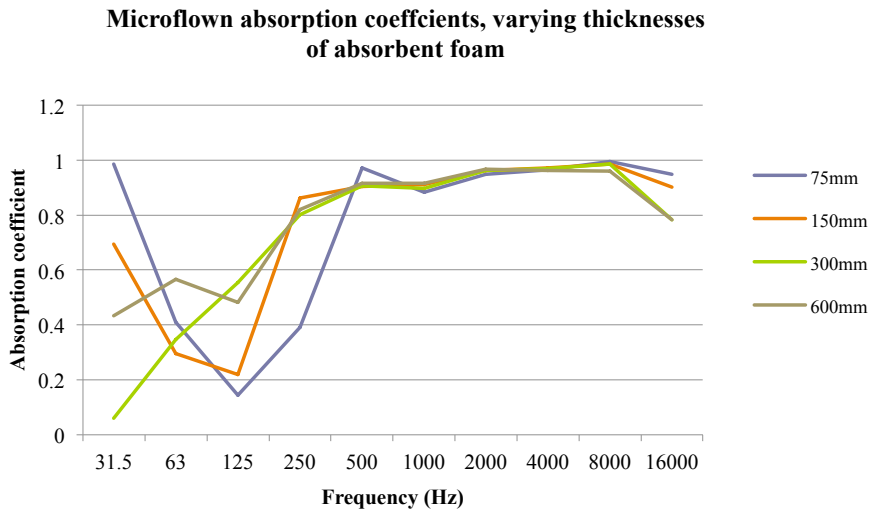

Figure 3: MF Abs cfs different thicknesses

To test for the effect of panel thickness, the 75mm panels were stacked in multiples. With the assumption of negligible interface effects between panels, this method was used to simulate panels 150, 300 and 600mm thick. It was not possible to compare with ISO 354 using these thicknesses as the lab possessed only enough panels to make $10m^3$ of 75mm foam, however it would be expected that roll-off frequency should move down the frequency range by an octave per doubling of thickness. The results reflect this reasonably well, although, ominously, low frequencies showed a wide, apparently almost random variance, almost between 0 and 1! This could be caused by phase ambiguity in the un-calibrated subwoofer sound source, background noise, wind noise (although

measurements were taken on a still day), or reactivity effects.

3.6   Design and Construction of Membrane Absorbers

To test low frequency performance of the Microflown + Subwoofer setup, test specimens with true low frequency performance were required. Porous absorber cannot easily fulfill this so a membrane absorber was designed for this purpose. Design resonant frequency was desired to be below 100Hz. Initial rough calculations suggested the chosen construction would satisfy this demand. The basic membrane absorber equation for resonant frequency was used.

$$f_R = \frac{60}{\sqrt{md}}$$

where f_R is the resonant frequency of the panel (Hz), m is surface density of the panel (kgm^{-2}) and d is depth of cavity behind the membrane (m).

Damping membrane absorbers normally results in a slight downward drift in resonant frequency due to the change from adiabatic to isothermal conditions within the panel. Experience has shown that for the damped absorbers, the equation

$$f_R = \frac{50}{\sqrt{md}}$$

should predict f_R more accurately.

Standard building materials were used: 3x1200mm x 2400 frames of 47x95mm (metric 2x4") stud was assembled. This frame was screwed to a 18mm thick MDF rear panel. The front panel comprised a 6mm MDF sheet. To make the best possible airtight fit, the seams of all joints except the front panel were sealed with acoustic caulk. The front panel was not sealed due to the need to open it to add damping materials during the tests. However many screws were used in order to ensure a secure and even join. There was a certain amount of overlap at the ends of the panels as the studwork was 2400mm long but the MDF panels were 8 feet (2.44m) long. This extra length was maintained to facilitate grip of these very heavy panels during setting up and storage.
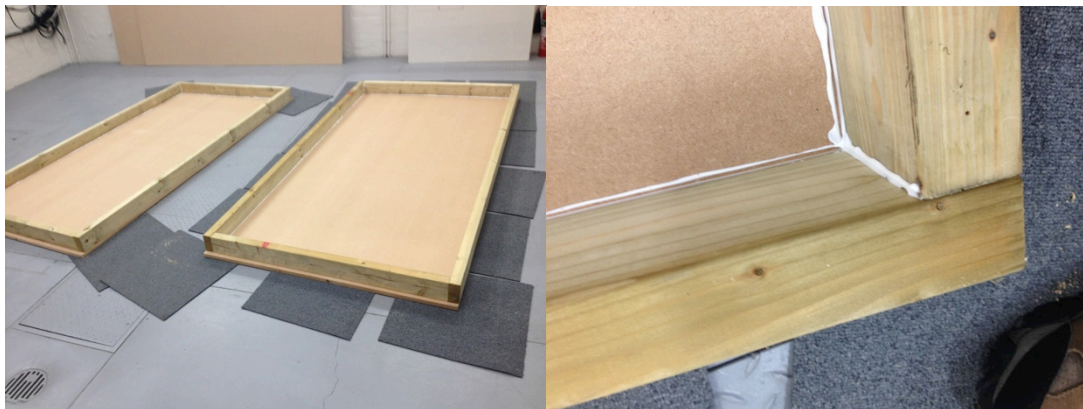

Figure 4: The absorbers under construction

Supplier data stated a mass of 13.396kg, or 775kgm^{-3} or 4.65kg/m^2 surface density. Therefore

$$f_R = \frac{60}{\sqrt{4.65 \times 0.095}} = 90.3\text{Hz (Undamped)}$$

and

$$f_R = \frac{50}{\sqrt{4.65 \times 0.095}} = 75.2\text{Hz (Damped)}$$

For reference the absorbers were tested in compliance with ISO354 in undamped and then

damped conditions with 75mm of RW3 Rockwool covering the whole internal area of all panels, leaving 20mm toward the front of the unit to allow free motion of the membrane.

For this test, three membrane absorbers of identical construction were used, each being 1.2m x 2.4m in size, giving a total area of 8.64m^3. This is just under the 10m^3 considered ideal by ISO 354.
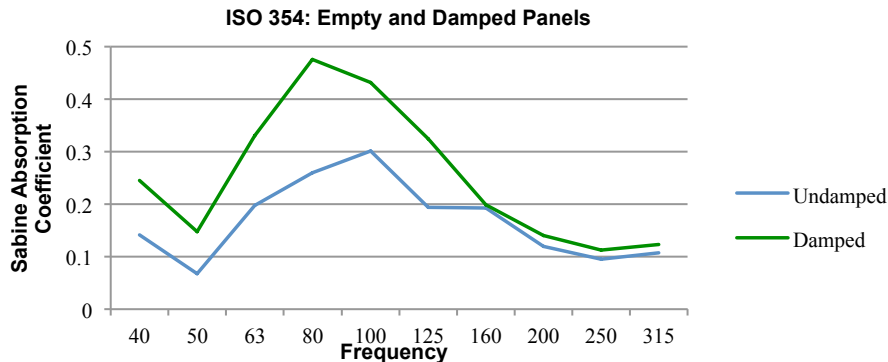

Figure 5: Absorption characteristics of damped and undamped panels as measured by ISO354

ISO 354 tests for the membrane absorbers suggested that the design equations have been more or less accurate. The result for the damped absorbers has a maximum effect in the 80Hz 1/3 octave band, close to the design value of 75.2Hz. Absorption coefficient is just under 0.5, although ISO354 measurements under-report absorption in this region (11) and the true peak may be obscured by insufficient resolution. Still, this is broadly what is expected for resonant absorbers.

The undamped absorber's result shows even less absorption, although the true peak is in this case surely much higher. It seems the peak absorption has occurred across two adjacent 1/3 octave bands or else the 3 panels have different f_R and thus absorption is hidden somewhat at this resolution. The nature of the absorption, however does seem to be narrower in bandwidth as would be expected.

3.7   Microflown + Subwoofer Tests on Membrane Absorbers

For the Microflown tests, one panel was selected and all Microflown tests done upon it alone. The panel was braced against the wall of the courtyard outside the Acoustics lab. For the sake of consistency it might have been desirable to place the absorbers flat on the ground, however the need to place the subwoofer at normal incidence precluded this as the means for suspending such a heavy object was not available.

Figure 6: Mounting for the subwoofer had to be improvised. Here a concrete slab is used to lift it for the

second row of measurements.

After an infinite termination calibration measurement was taken, further measurements were taken at the surface of the membrane. Since this technique measures the impedance and absorption at a specific point, a series of measurements would need to be taken to average the behavior of the

membrane as a whole. It was assumed that the panel was symmetrical in vertically and laterally. In this manner the 12 measurement locations were all taken in one quarter of the absorber. Four locations laterally at each of three heights were chosen for measurement. If the membrane moves at it's fundamental resonant mode as predicted then the maximum motion should be in the centre of the membrane, with the magnitude of vibration getting less toward the static mounting points at the edge. The intent was to evenly space the measurement locations, however, mounting the heavy subwoofer was not easy and supports had to be improvised from materials found around the lab, so measurement heights especially were not evenly spaced. Mounting both the sensor and the subwoofer proved quite difficult. The probe needed to be as close to the membrane as possible, yet some gap was needed especially now as the membrane was moving when activated. The probe was retained in the mounting chassis and stand as supplied, yet the courtyard surface was somewhat uneven and some effort had to be made to keep the sensor close and oriented correctly. Likewise the subwoofer is a heavy and a stand capable of bearing it's weight was not available. Thus for the lowest level of measurements it was placed on the ground. For the next row of measurements it was raised to the appropriate level by being placed on a concrete slab and for the final row was placed on a steel trolley. Any practical setup would require a sturdy support at all heights and hence consistent propagation.

4. RESULTS

Results for each measurement location are presented at the end. They are puzzling. It can't be said that they really reflect the expected performance based on the design criteria. The undamped panel results show great variance between measurement locations and it's hard to pick out common trends between results. Membrane absorbers should display extended reaction and hence the general resonance of the membrane should be observed to some degree at each measurement position. Having said this some broad patterns emerge. Resonance at 40Hz along the bottom edge and through the panel centre, although in the context of more broadband behavior in the latter. The design frequency predicts a single strong resonant frequency, and although this is somewhat of a simplification, we must expect strong absorption at f_R at some locations. The damped panel shows consistent resonance, but around 160Hz, among other localized behaviours.

It is presumed that some of these anomalies might be averaged out in a series of measurements. The spatial variance of the measurements is presented in Figure 7, showing wide variance in the undamped condition, notably below 50Hz, with a peak variance of 12, and at the design frequency, perhaps indicating modal behavior. The peak in variance at 80Hz might be expected as the damping effect of the rockwool should indeed cause a significantly lower peak absorption that that of the undamped panel.
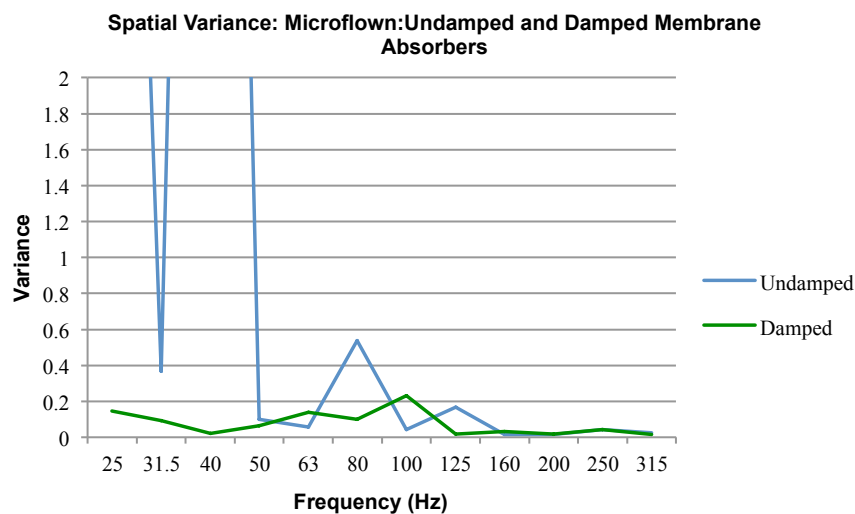

Figure 7: Spatial variance of Microflown + Subwoofer measurements for the membrane absorber

Averaging these results might be expected to yield an overall performance in line with expectations. Averaging at 1/12 octave filtering displays what appear to be strong modal peaks, but these are as much the result of negative coefficients and this makes it hard to learn anything from these results.
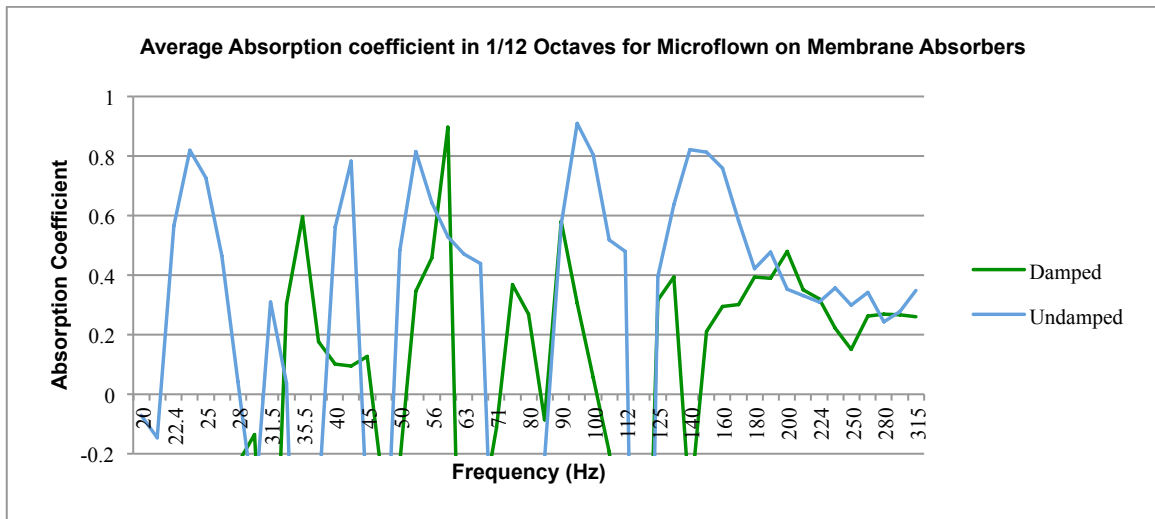

Figure 8: Average absorption coefficient for Microflown + Subwoofer for Membrane Absorber. In 1/12 Octave bands.

5.   DISCUSSION

5.1   Membrane

While the dominant mode of resonance for the membrane would be expected to be around the design frequency, if damping is sufficient, then other modes of vibration could play a role

Given that the membrane has mass and hence inertia, then resonance depends on incident energy. In this experiment, a reasonably quiet sound source had to be used to avoid overloading the velocity sensor. It is possible that this reduced level failed to set the absorbers in to true resonance and other effects (stiffness, surface waves etc) predominate.

Resonance also implies different phase change at resonance compared to below or above resonance. This is critical to acoustic problems, but given the complexity of the membrane absorber, an in depth discussion of this is beyond the scope of this report.

5.2   Negative Coefficients

This test program has been blighted by the negative absorption coefficients given by the Microflown. Indeed, this characteristic is noted by Bilova and Lumnitzer in the operation of the impedance gun in stock condition (12), Brandao et al associate this behaviour especially to the Plane Wave correction model at lower frequencies, although their report does not investigate below 100Hz (13), and Microflown data by contrast associates this behaviour with other models and their assumption of local reactivity (14). The Microflown eBook mentions that low frequencies (below 200Hz) are prone to negative results. The reason, as explained by Brandão et al lies in a particular term in one of the equations used to determine reflectivity factor which in turn gives absorption coefficient. They describe that the behaviour has proved consistent in experiments and so multiple averaged measurements may not remove it. (13)

5.3   Other Metrics: Coherence

The impedance gun presents a wide array of data, beyond absorption coefficient. These other metrics were studied to see if light could be shed on the results. P-U Coherence was proposed by Jacobsen in the 1980's as a way of characterising sound fields. He describes P-U coherence as being a "rather fundamental" indicator. (15) This interest is primarily as this (P-U) coherence can indicate the number of sound sources present: of prime interest in noise control applications. In the case of the Subwoofer, we are measuring in the geometric near field, so coherence should indicate which frequencies are free of the near field and which are still producing Fresnel effects.

Additionally, the sound field at the measurement point comprises not just the subwoofer as a source, but also the membrane, which reradiates sound from a point very close to the sensor, producing yet more complex interference effects. Each material reflects differently depending on it's absorption characteristics, so at any given frequency, the coherence will change with absorption.

5.4 Coherence with the Membrane Absorber

We should observe spatial variances within the membrane, the centre of which should be subject to most resonance, and the edges where the membrane is supported rigidly should show almost no resonance. Figure 9 and **Error! Reference source not found.** show the coherence at two averaged edge measurement locations (Measurements 3 and 4) and two averaged central measurement locations (Measurements 5 and 10) for the undamped and damped membrane absorber. Measurements with negative absorption coefficients were excluded.
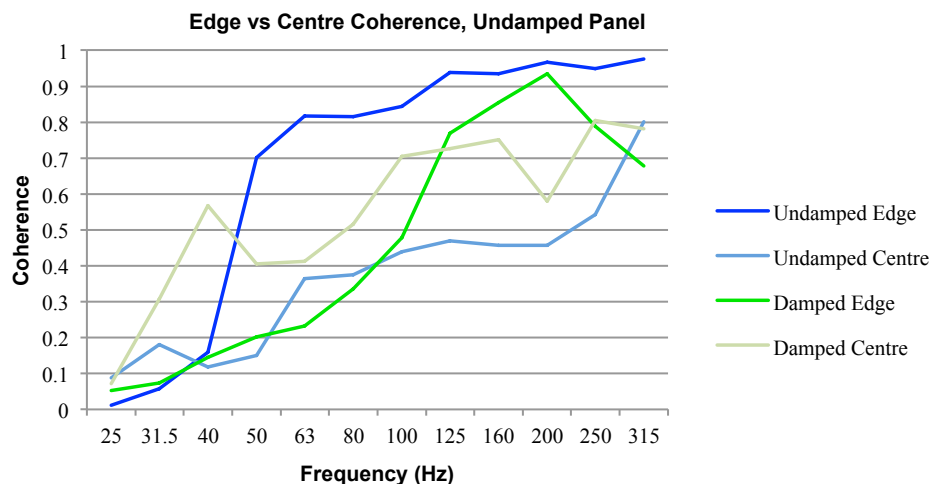

Figure 9: Coherence at the edge and centre of the membrane absorber

From Figure 9 it can be seen that the edge measurement, which might be assumed to be more perfectly reflective, rises quickly to approach coherence by around 70Hz. The centre of the panel, where resonance is presumably taking place more strongly displays delayed approach to coherence until around 200Hz when the graph rises quickly towards coherence.

5.5 Sources of Error

Many sources of error are possible in this difficult type of work, in fact this seems an especially difficult measurement problem. As an initial test, only one measurement per position was performed, more should be taken to explore the ensemble variance of the method. Background noise is predominately at low frequencies: near to the source, particle velocity is very high, and this precluded sufficient source level to overcome background noise. Close to the low frequency source as we are at the measurement distance, much non propagating flow is present. P-U probes are known to be sensitive to reactive sound fields. (13) A membrane absorber is a moving surface, which moves in resonance with incident waves, although not necessarily in phase with them. As such it is not locally reactive and is neither a fixed reflector, so existing correction formula do not take account of this.

In the reverberation room, the absorbers were mounted on the floor with membranes facing up, while for the Microflown tests, they were mounted vertically against a wall. It was assumed behaviour was the same, however, what quantitive difference the effect of gravity has on the panel is unknown.

5.6   The Measurement Environment

Several effects can be expected to have a significant detrimental effect on these results. It can be difficult to generate a source sound loud enough to overcome background noise, especially at low frequencies. Hence the particle velocity at the measurement position is generated by the source, but the pressure at the measurement position is derived from the background noise, therefore the measurement is not valid at frequencies where velocity and pressure are not coherent. The degree to which the 1st (calibration) measurement accounts for this should be explored. (9)

To obtain a louder signal to overcome background, measurements could be repeated with a swept sine source, whereby a louder signal can be obtained at each frequency in return. Brandão et al report improved performance with this method. (13) This may help this problem, but the concern is that this is no longer a representative method of excitation for resonant absorbers in a music context.

Although these measurements were carried out on still days, and the Microflown tests show good rejection of wind noise below 2ms^{-1}, wind noise notably occurs below 100Hz. This should be quantified properly using an artificial wind source.

The impedance gun, to be useful, must be to some degree an in-situ method (although carrying a subwoofer around will never be convenient) and wall constructions and treatments for Architectural and Building acoustics would be the real-life targets. For this reason the effects of room modes cannot ultimately be skirted as they have been here. Practical measurements will be in rooms with modal effects and they must be accounted for, or even used constructively. (16)

5.7   Low Frequency Calibration

Microflown have also attempted similar low frequency work to that of this report. Their challenge was to create a sound source, which produced high pressure levels with acceptable velocity levels within a car cabin. Their solution was a dual monopole loudspeaker, since for omnidirectional characteristics, the source should be small compared to wavelength, yet to achieve high pressure with acceptable velocity requires a source with greater diameter. They calibrate using a tube method and report (briefly) on results down to around 40Hz. (9) 11-7. Further work with the current apparatus requires an accurate model of the JBL subwoofer's propagation in this context.

5.8   Future Work

The membrane absorber proved an intriguing target, and it would be especially interesting to incorporate a vibration measurement to more fully understand the membrane's motion and hence radiation and reflection properties, especially hydrodynamic near field effects

Castagnede et al present a very interesting method, measuring the absorptive properties of porous absorbers in the audio range using a non-linearly demodulated ultrasound array source. They report good results down to 100Hz with a simple, portable in-situ setup. This may be a way around some near field effects (17)

6.   Conclusion

Replacing the Microflown Impedance Gun's stock spherical sound source with a Subwoofer produced a functional experimental setup for exploring the nature and problems associated with low frequency absorption measurements. This arrangement, although ad hoc in nature, achieved performance broadly comparable to ISO 354 for porous absorber samples. This same setup did not

give results in line with expectations for a resonant membrane absorber due to near field effects effects such as the reactive field close to the sample, in which the P-U probe is known to perform badly and uncertainties stemming from the Microflown software returning negative absorption coefficients.

The nature of Intensity sensors means it is difficult and time consuming to produce random incidence absorption coefficients since they measure a small area of space, rather than the effect on a room as a whole. Sadly, designers and consultants normally require the latter type of data, and this is the strength of ISO 354.

It is noted that the ISO 354 method is not valid below 125Hz and although modification have been put forward by Zha and Fuchs (18) (16) there is no standardised measurement method with which to compare the Microflown + Subwoofer results.

A modified method may be possible, as the Microflown sensor and software are suitable for this frequency range. Techniques used for Noise Control and vibration may be useful as low frequencies and near field effects are commonly encountered in this field. Some characterisation of the sound field in the vicinity of the sample must be incorporated – metrics such as Coherence may have a part to play.

The Microflown system although requiring some forethought while measuring, provides an excellent platform for experimental acoustic measurements, providing a wealth of data for analysis.

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