

Tuning Audio to Rooms: Small Pub Venue Acoustics and PAs

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Introduction

This research project will explore how to optimise the quality of sound for live music performances in small pub or bar venues. I have made my living, wholly or in part, as a musician working in small venues for around 20 years. I suffer from tinnitus, have significant hearing loss at around 6k hz. I use hearing aids in both ears and regularly attend live music events. This research is important to me personally and I hope to pass on what I learn to my peers, friends and colleagues within the music industry. I am particularly interested in the effects of resonant frequencies in the rooms and halls I play in. I will investigate how to accommodate the varied nature of the room shapes, the impact of materials used within the rooms such as flooring, wall covering, soft furnishings, windows etc, the numbers of people absorbing the sound and the impact of background noises such as talking on the sound quality. Preparing for a performance takes many years of practice and attention to detail but each room has its own characteristics. Tuning a P. A. to each room should result in a consistency of tonal properties at each performance.

To what extent is room acoustics a problem for small venue performers? When you get a good sound, it enhances the overall performance, it boosts the performers confidence and gives them a lift, and conversely when the acoustic is not right it can be very distracting and impact on the performance in other, negative ways. The same is true for the audience. A great performance can be ruined if the sound quality is poor. In the main, it is the responsibility of the artist to achieve a good sound due to the fact that, in most cases, they do not have a sound engineer. In general, most pub bands and performers take a hit-and-miss approach to sound preparation such as adjusting the equalisation by ear. This is not efficient or accurate.

Almost everyone these days has a computer of some description and applications are available to analyse resonant frequencies in a room. Having invested hundreds, possibly thousands, of pounds and spent many, many hours practicing to throw it all away on poor sound preparation seems foolish. Doing the analysis and making the appropriate adjustments beforehand allows the performer the opportunity to obtain a good sound every time.

My personal experience of acoustic problems includes feedback, which is probably the most common problem, and unpleasant tonal artefacts, i.e. the sound is too bright or bass-heavy. Venues with flat, hard walls, such as school halls or gyms, can produce a sound that reverberates and bounces around, causing loss of clarity.

Feedback for example can be affected by volume levels but isolating which frequency is being troublesome and reducing it, can mitigate the issue. The volume needs to be loud enough to carry over or cut through the sound of the audience. In the type of venue I will be discussing, audience members will be chatting to their neighbours, ordering drinks and unlikely to simply listen. That, however, is not an excuse for neglecting one's sound or performance.

I will be investigating what happens when sound waves hit objects, bounce back and are superimposed upon one another; how the amplitude of the waves is added together or cancelled out. I will touch upon the maths to calculate the points at which these "standing" waves are added together, how it effects the strength of these standing waves at any given frequency and is dependent on the properties and dimensions of the room. At a gig, there are obviously no areas of silence in the room. There are simply points at which certain characteristics are more prominent than in other locations.

The aim of this dissertation is to research, understand and be able to implement techniques to manipulate resonant frequencies in a live, small venue setting, to optimise the equipment used. I am aware, from experience, that increases in amplitude across a range of frequencies are not uniform. They are dependent on the properties within the space they are confined to and the character of the speakers used.

Playing amplified music at low level cuts the bass response which needs more energy.

Turning up the volume will of course raise the level overall but various frequencies will respond in different manners. As the volume rises the bass, due to the speed at which it travels, the wavelength and the energy it carries, will become more robust and the overall sound will become fuller.

I will be investigating the reasons for, and ways to level out, these peaks and troughs.

The final point at which a sound engineer has control over the sound is when it leaves the mixing desk or amplifier and exits from the speakers. Beyond that point the room has command.

Chapter 1 – General Overview of Acoustics on Music Sound Production

What is sound?

Sound is a longitudinal, mechanical compression wave. The greater the compression the greater the amplitude. As the speed of sound is constant (depending on altitude) the more rapid the frequency, the shorter the wavelength must be and the higher the pitch (Glenn Elert, 2019). This gives rise to, among other things, the Doppler effect. An approaching sound source is louder and higher pitched at a given distance than a retreating sound source at the same distance.

Our ears collect these pressure waves, funnel them to our ear drum which vibrates back and forth. The movement is carried to our inner ear via the smallest bones in our body, the malleus (hammer), the incus (anvil) and the stapes (stirrup). Our inner ear is filled with fluid and lined with tiny hairs that move with the changing motion of the fluid. Nerves transmit the movement of the hairs to our brains which decodes the information into what we perceive as sound.

Our ears are so acute that we can identify the direction a sound came from by the extra time it takes to reach the ear furthest from the sound as opposed to the ear nearest to the sound. The outer ears affect the tonal properties of the pressure waves and contributes to the assessment of point of origin. Like sight, hearing is not fully understood.

How do surfaces respond to sound waves – are new sound waves created, reflected or generated? The way surfaces react to sound depends on their constitution. What they're made of, the thickness, porosity, hardness, smoothness, size, shape, mass and so on. We take advantage of these various properties to amplify or attenuate sound and to manipulate tone.

What are acoustics? Acoustics are the perceived effects of influences upon sound such as tone and reverberation. How sound transfers through various mediums and dissipates through different mediums.

The greater energy required by the low end is transferred to objects more than the smaller amount of energy in the higher end of the frequency spectrum. This is apparent when one

stands outside a music room with the door closed and the sound is muffled. The high end is more effectively blocked and, although much of the low end is contained, a considerable amount of energy transfers to the doors and walls causing them to vibrate. These vibrations cause the air particles on the outer surface of the structure to vibrate which can be heard outside. (Rennie, J. 2012) Sound vibrations that are not transferred or reflected and dissipate within objects are converted into heat.

How does sound behave in small areas? It is not unreasonable to extrapolate from this that walls, doors and windows, act in a similar way to speakers sending compression waves back into the room. That being the case one could also conclude that such surfaces would behave like drum skins or speakers adding their own characteristics to the sound dependent on their properties.

It could also be concluded that corners, where two or more surfaces meet, are more rigid which explains why such regions tend to sound more bassy. The sound vibrations do not dissipate as easily, though that could be more to do with the compression waves hitting the wall, floor and ceiling, spreading out and meeting in the corners building up even greater sound pressure. An identical process can be observed in water where waves hit adjacent walls and rise to their highest point where the walls meet. The combined pressure forcing the water upward.

David Santo Pietro (2019), talking about instrument strings, discusses the calculation of the wavelength of any harmonic which describes the creation of nodes and anti-nodes. Nodes are the points of no motion within a wave while anti-nodes are points of maximum motion. His calculations are academic which do not take into consideration the peculiarities of individual situations, whereas in the real world the material the strings are made from, the plucking action, the actuator (fingers or plectrum), the quality of manufacture, the other materials the instrument is made from and many other variables will influence the motion of the string and the resonant frequencies constructed and destructed. This is why one instrument or string sounds different to another. Every note played is unique.

Applying his ideas to room acoustics it might be possible to infer that within a room, there will be nodes and anti-nodes overlaying each other and the result will give a perception of tone and effect the sound quality. Bare, smooth walls for example would be highly reflective

of sound waves over a wide-range of frequencies, whereas curtains and other soft furnishings will reflect sound waves much less so and therefore tend to dampen sound particularly at the high frequency end.

In the latter example, the sound waves cause this less dense and reflective material to vibrate. The higher frequencies which have less energy will dissipate throughout the material be converted into heat and be lost. This phenomenon is taken advantage of when using foam rubber in acoustically treated rooms such as studios.

In addition to the texture and rigidity of surfaces, mass is also critical to the behaviour of soundwaves in the room, specifically in the containment of sound. Therefore, concrete walls will stop sound passing through and reduce leakage the of sound whereas low mass materials such as egg boxes do little to impede the travel of sound waves through them.

Sound, which is a type of energy, when hitting a wall, or any object, must go somewhere. When a wave hits an object which it cannot easily pass through, it is inverted and reflected back. When the sound wave travels back along itself, now inverted, the sound wave amplitude is alternately increased and cancelled creating nodes and anti-nodes. It is an oscillation between the two points that, depending on where an individual is standing in a room, effects the tonal properties perceived.

Much like a wave in the sea, sound waves, seem to have direction of travel. This is not the case. The compression works in a knock-on manner. A forward and backward motion of air molecules.

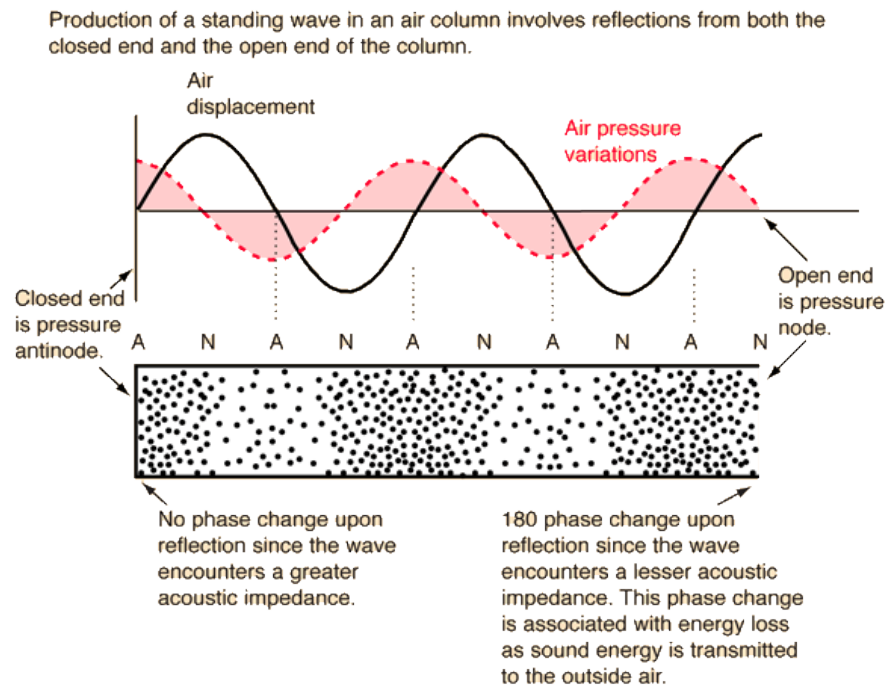


Fig. 1 Standing waves image showing nodes and antinodes (Nave, 2005)

The black line (Fig 1) depicts the standing waves. The broken red line depicts a travelling wave like a wave in the sea. If a reflected wave were overlaid on the red line traveling in the opposite direction, the points at which the anti-nodes cross will result in the standing waves. This effect can be created visually using Kundt's tube experiment whereby light weight particles, such as the polystyrene balls in the image below, literally stand upon one another between the positions where standing waves occur. They are pushed out of the areas of highest air pressure.

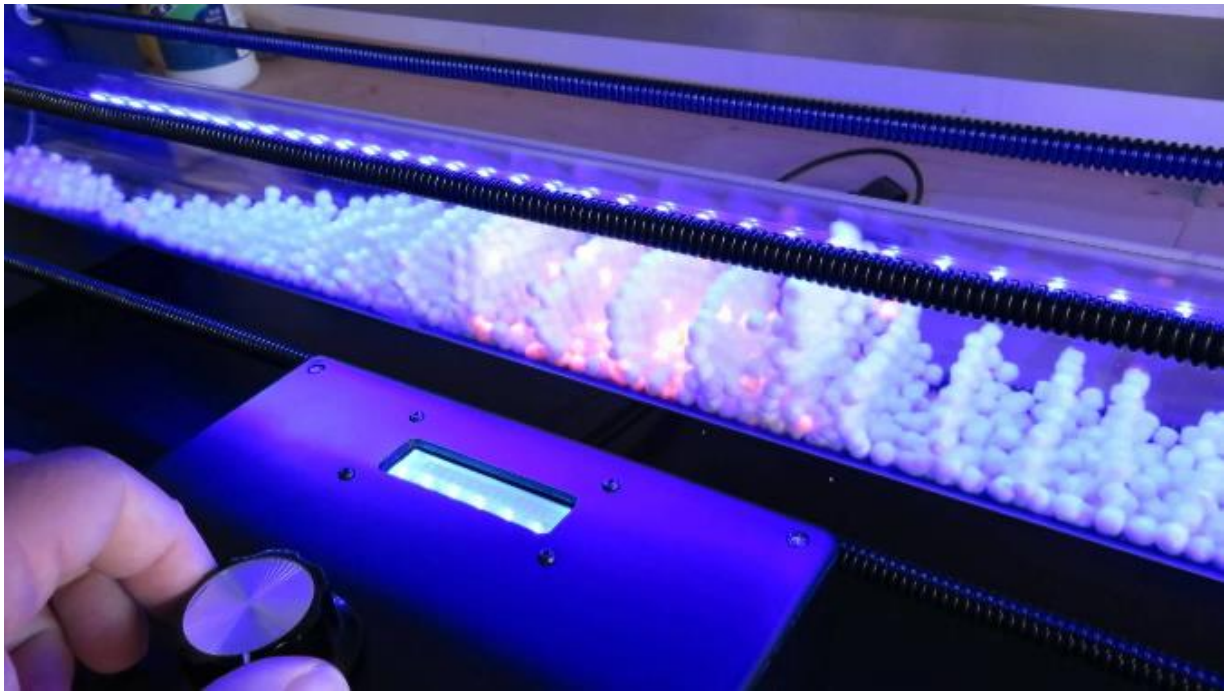


Fig 2. Kundt's Tube Experiment (Povdude, 2014)

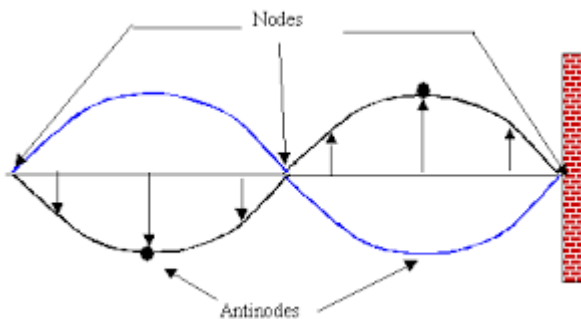


Fig. 3 Standing waves showing nodes and antinodes (Antonine-Education, n. d.)

For any given frequency the nodes and anti-nodes will be closer or further apart, giving the tonal properties of the space and specific locations within that space. So, depending on the reflective property of an area, and the particular wavelengths being bounced around that space, it might be the case that there is a loss of bass in one area whereas the higher frequencies might be more prominent in another.

The wavelengths of the open strings of a bass guitar are

G- 97.9989Hz -11.531 ft.

D- 73.4162 - 15.392 ft.

A- 55.000Hz - 20.545 ft.

E- 41.2035 - 27.425 ft.

[20 deg C (72 deg F) @ sea level]

(TalkBass, 2007)

In a practical sense it is not possible to tune a room to each individual person, but it is possible to mitigate these unwanted frequencies generally and, in effect, create something of a blank canvass on which a performer can present their work.

The Acoustics Project in Gothenburg, undertaken in Henriksberg Rock Club, investigated and addressed the problems faced by artists, the venue and staff.

The issues were typical of pubs and clubs. There was a corner stage, stereo P.A., monitors positioned on the floor (on the stage), a bar in the music room at which the P.A. was pointed - a simple, normal, layout.

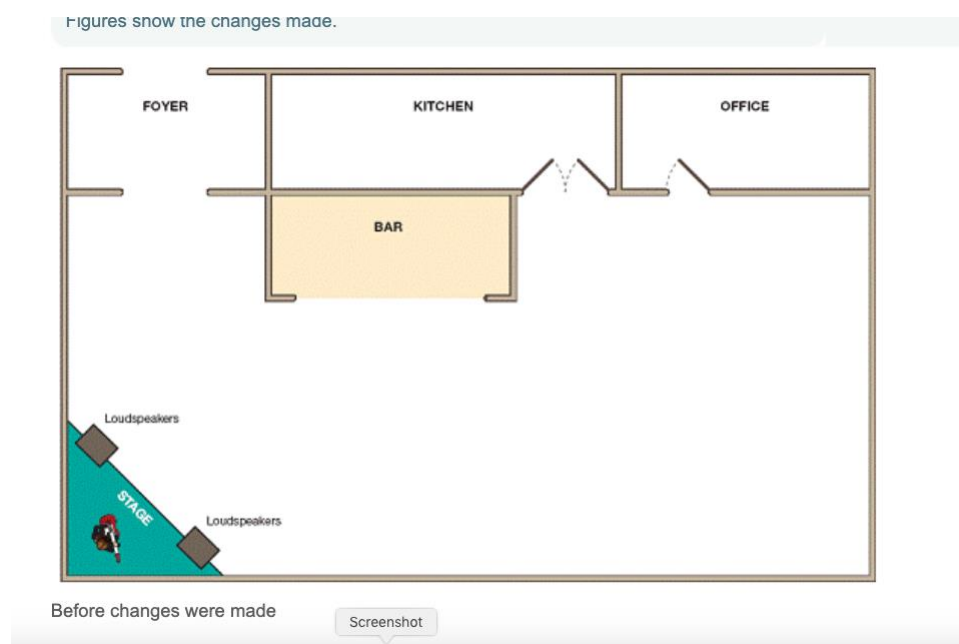


Fig. 4 (Sound Advice, 2019)

It was found that the sound levels varied at different places in the room, on different nights and with different bands. Staff were being exposed to dangerous levels of noise. 92dB for the bar staff, 94dB the glass collector, 91 dB door staff and a reference point measured 103 dB and up to 115.7 dB on occasions. (SoundAdvice 2007)

At all the events measured, the levels reached well above the United Kingdom's upper limit of 85dB (Legislation.Gov.Uk, 2005) even after changes were implemented.

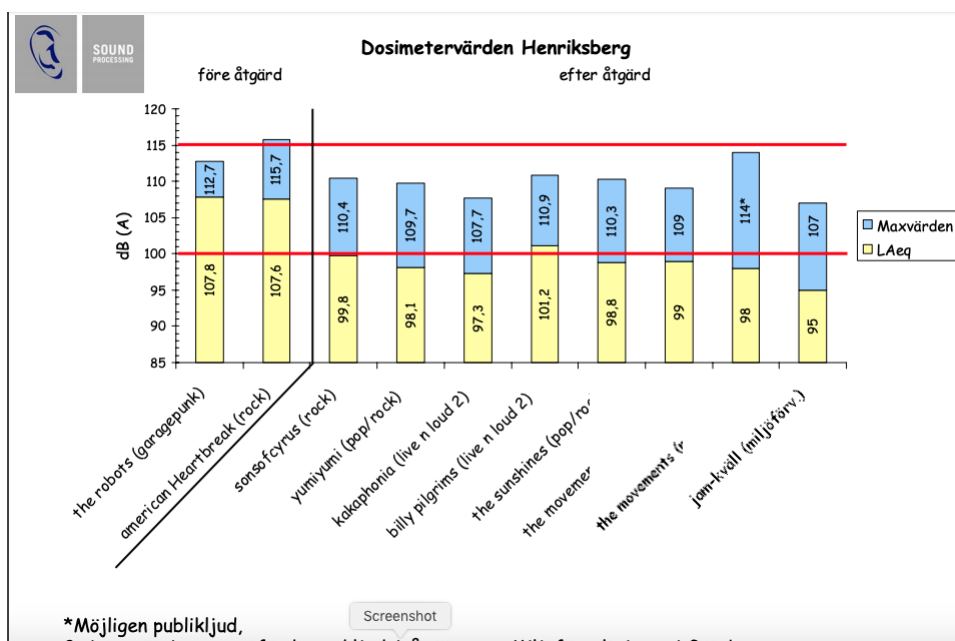


Fig. 5 (Sjösten, n.d.)

It's clear that this is not good for anyone. The staff, the artists or the audience. Aside from the damage to hearing, clarity will inevitably be lost. According to (Fazenda, 2001) early reflections, under 15 ms cause lack of clarity. Sound travels at 343 mps therefore, in a small venue, sound with enough energy to reflect from one surface to another several times, will result in many reflections within that time frame and create a blurred sound image.

Hearing is our first sense developed in the womb, and like sight, is not fully understood. It gives us a sense of spatial awareness and an impression of our surroundings. Interfering with it can destabilise us or cause discomfort.

The time sound takes from the point of origin to meet the listener and then the time follow-up reverberations take to meet the listener is important for clarity. There appears to be a critical period of 15 milliseconds.

In an ideal listening environment, according to Fazenda in *A study on acoustics of critical audio control rooms*, (2001, p. 11) 'When listening in a control room the sound within the first 15ms of a pressure front should reach the listener's ears without being affected by reflections introduced by the room.' They go on to say that, although reflections outside that range are desirable, if reflections are present within that time, there is a perception that the room is smaller than it is.

Longer delays and reverbs are often introduced synthetically by musicians who use amplification. It will not be possible to get the same natural reverberation in a pub gig as in concert halls etc. but simulations should be achievable. It is common practice for guitarists to use simulations of classic guitars and amps. That being the case the same should be true of halls, rooms and arenas. Such a scenario would allow a reproduction of Eric Clapton's Stratocaster, through a Vox AC30 at the Royal Albert Hall.

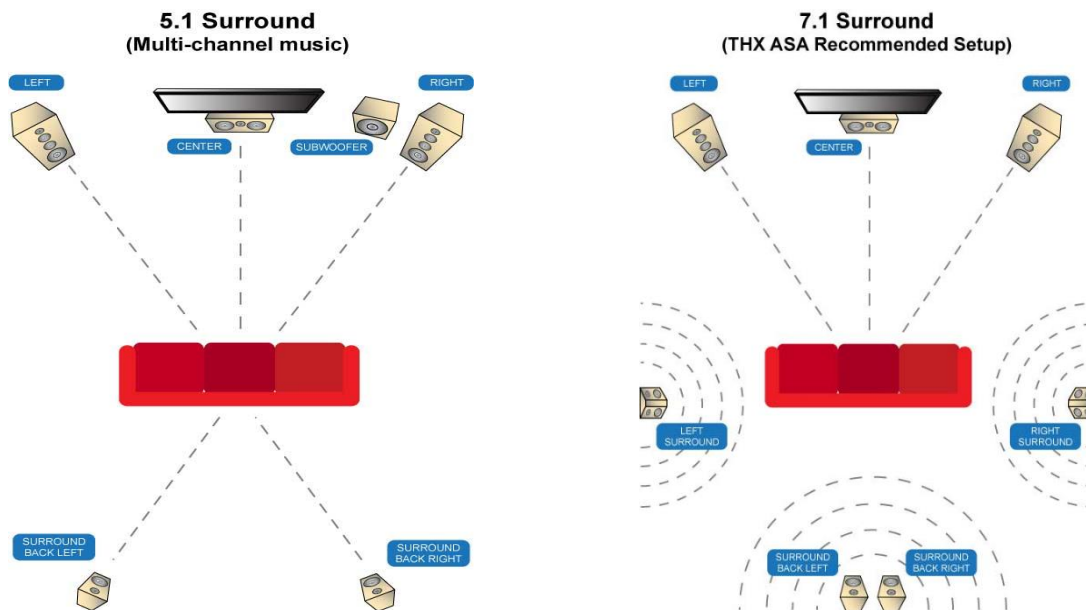
The literature and research on acoustics has been mainly confined to concert halls and theatres, including cinemas. While these are much bigger spaces and tend to be more limited shapes and built for purpose, it is still useful to consider what the research in this area has to say.

Concert halls and similar venues tend to have a shoe-box or a fan shape. A subjective ranking of halls, undertaken by Baranek (2016, p.2), showed the shoe-box shaped halls produce sound more popular among aficionados of orchestral performances than the fan shaped concert halls. Fan shaped halls typically have the musicians located at the narrow end with the audience spread more widely across the back of the auditorium. Baranek observed that the fan shaped halls had strong early reflections from the ceiling and no reflections from the side walls. In the shoe-box shape halls the sound reflected early and with strength from the side walls followed by a weaker reflection from the ceiling giving more pleasing reverberation. Another interesting aspect was that the halls ranked highest had assorted artefacts, nooks and crannies on the upper walls and ceiling.

Some audiences reported their preferences for sitting in the middle auditorium towards the back whilst other audience members said they favoured the front of the balcony which gives a more immersive sound experience. The middle of the lower auditorium still gives some reflections from the walls but has a little more clarity. This information was gathered by Baranek (2016, p. 2) who set up multiple microphones in several concert halls, recorded performances and played back the recordings through multiple speakers in one 'silent' anechoic room so that he could reproduce the properties of each of these venues in a single location played back through multiple speakers. He brought in season ticket holders who were familiar with particular venues to listen to the recordings.

In the shoe-box shape, the orchestra is located on the short wall at one end, whereas in small venues the musicians could be located anywhere, against a long or short wall or in a corner the research does however, show how important reverb is to the satisfaction of the listeners. It may suggest that small venue performers might reconsider the alignment of their speakers. They could consider angling them to spread the sound and bounce it off the walls. They might benefit from more than a stereo pair to simulate a larger hall. Attempting such an arrangement could give rise to phasing issues or create standing waves.

In concert halls the sound comes from the musicians on the stage at the front of the hall. Cinemas in contrast often have 5.1 or 7.1 surround sound. Although it's not shown on the right-hand image in Fig. 7 below, it's quite normal to include a sub-woofer in a 7.1 set up. The sub-woofer positioning is not critical as the frequency directionality is indefinable.



Figs 6 & 7 (Deboer, 2015)

Speakers can be ‘tuned’ to a room by taking out certain frequencies. In his video, Steven Thomson (2018) demonstrates how the sound quality of a radio weather forecast could be significantly improved by removing or attenuating resonant frequencies. He analysed the resonant frequencies of the room using pink noise. Pink noise is sound, like static, which is equal in amplitude across all frequencies and is therefore a good measurable reference point for sound analysis purposes. (Brashler, 2016)

Pubs themselves tend to be complex shapes with alcoves, obstructions, archways etc.

What sort of sound do audiences want at rock gigs. Audiences still want to be able to differentiate the different instruments, but they want the sound to overlap and tie together. As opposed to being able to hear the separate instruments as individuals, the audience generally want to hear the whole, without any one thing being lost or overpowering.

As with all musical performances, audiences also want an emotional and physical experience of the music, but without the music becoming one big ‘mush’. A certain amount of clarity is required whilst still maintaining cohesion.



Fig. 8 Example of spectrum analysis showing highs and lows within a sound (Ableton, n.d.)

The above image shows a visual representation of pink noise. There is a bump across the middle frequencies and a fall off at the higher frequencies.

Compensation can be achieved using a graphic equaliser to raise the upper range and cut the mids as shown in Fig 4.

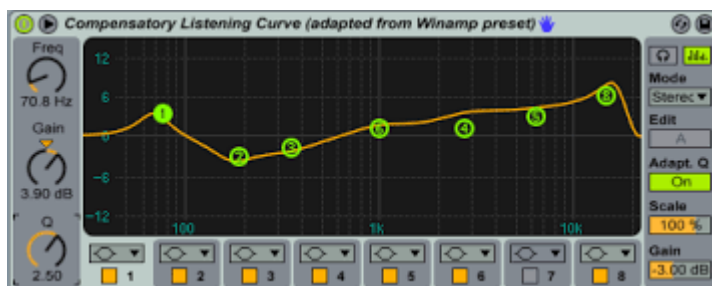


Fig. 9 Graphic Equaliser showing which frequencies are being raised or lowered (Ableton, 2014).

Pink noise is the starting point for adjusting the acoustics of the room. Pink noise can be used to establish a reference point. It is produced by an electronic pink noise generator and is sent through the PA equipment. A microphone is situated in the middle of the room and that receives the pink noise being generated, it is then taken back into the computer to a spectrum analyser. This will be represented on a computer screen as a wave pattern and shows the peaks and troughs. The peaks can be cut and the troughs raised to flatten excesses at any particular frequencies, and therefore provide a base from which to work from. The resonant frequencies, those standing waves that cause problems, can be taken out of the picture. The sound can then be manipulated. If the guitarist likes a bright sound for example, then that can be produced by using their regular settings on the amplifier.

At this point a consideration of psychoacoustics is in order. Psychoacoustics is the study of the physiological responses we feel as a reaction to sound and is important in understanding how people respond to audio-stimulus at an emotional level, such as fear, excitement, sadness and happiness for example. That is why we have music in films. Sound enables people to comprehend their environment: the size of the area they are in, the quality of the substances and materials surrounding them, a sense of inside and outside.

Very 'dead' rooms can be tiring. It is hard to know why this is. It makes it difficult for the individual to assess their surroundings particularly when in darkness. Subjects have described feelings of claustrophobia, disorientation and nausea. (Veritasium, 2014)

There are reports that some people in anechoic rooms, which are designed to be as near silent as possible, experience hallucinations. The brain seems to recalibrate to such a degree that one's blood, heartbeat, swallowing and stomach can be heard. The effects of sitting in darkness in an anechoic chamber are such that Daniel et al (2014) concluded that 'The findings suggest that even during a quite brief period of sensory deprivation, perceptual distortions, and other psychosis-like experiences are common in the "normal" population" and " ...would seem a useful paradigm to model psychotic symptoms,...'. The methodology of the experiment has, however, been questioned by Vaughan Bell as mentioned by Trevor Cox in The Sound Blog, Despatches from Acoustical and Audio Engineering. (2013)

In this chapter I have shown how audio-stimulus has psychological and physiological impact on people. Sound can be used intentionally as a tool to create these responses. Because we respond on such a fundamental level, and we are so sensitive to noise, getting the sound quality of a gig right is essential.

Chapter 2 – Implications for Small Pub and Club Venues

There has been very little research undertaken regarding acoustics in small venues other than studies relating to occupational noise. One study by Ramakrishnan and Dumoulin (2016, p. 1), underlines this problem. Many pubs are old and were built before concerns about acoustic and noise intrusion were considered. In older pubs, different sorts of instruments were used with no amplification. Similarly, the surrounding buildings were different, with fewer concerns about noise pollution. As Ramakrishnan and Dumoulin also point out, little attention is given to 'acoustical separation' between spaces. Many venues have multi-function spaces, including eating rooms (2016, p.1).

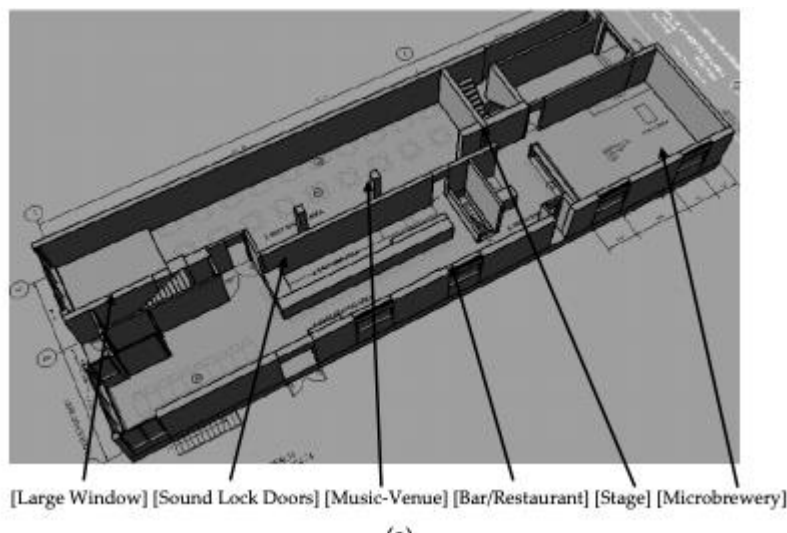


Fig 10. (Ramakrishnan and Damoulin, 2016)

In the study they undertook in Canada, a vacant unit was converted into a bar/music area, with two music spaces, one for acoustic performance and the other for amplified music (2016, p. 3).

Structural inadequacies have an impact beyond getting a good sound. Poor sound insulation can result, and has resulted, in the closure of many live music venues due to noise complaints by nearby residents. The Music Venue Trust has lobbied the UK government to introduce building regulations that require new builds, located near existing live music venues, to be installed with sound insulation to reduce complaints and protect venues from closure. In a press release, the then Secretary of State for Housing, Communities and Local Government, Sajid Javid said 'Housing developers building new homes near music venues should be

responsible for addressing noise issues in a move to protect both music venues and their neighbours...' (Gov.UK, 2018). With good sound engineering volumes can be brought down and sound quality improved without compromising entertainment value.

Once we have an awareness of how sound behaves then it is possible to manipulate sound to accommodate those behaviour patterns. For example, if a venue space is acoustically analysed noting how sound reacts in that room, by exaggerating and reducing frequencies the necessary compensations can be made to idealise the sound produced at that venue.

It may not be possible to work with acoustics in the way that concert halls work as there are too many variables. Concert halls tend to have high ceilings, large flat walls, stages above the auditorium and large volumes of open space which allows sound to travel and reverberate unimpeded. By contrast pubs and small venues have smaller volume capacity, arches, columns, pillars, wall hangings, pictures, furnishings etc.

Modern mixing desks often have software which allow settings to be saved for each event. The settings can be loaded again when returning to that venue. This means, assuming there have been no major changes to the structure or furnishings, analysis need only be done on one occasion.

There is software that will measure resonant frequencies of the room and will automatically control those, but as soon as the place is full of people, everything will change. How could this be accommodated for. As shown by Dr. Eugene Ackerman et al (1962) our bodies will absorb high frequencies more than low frequencies. Although the report describes the absorption rate on bare skin and individual limbs and acknowledges clothing would significantly increase the absorption coefficient, it gives a rough guide to allow adjustment to be made for the number of people in the room.

Conclusion

This study aimed to explore the factors that can impact on sound quality in a small venue and methods for improving sound quality. It was found that to achieve a good sound in a small venue the first thing to do is establish what characteristics are naturally present using computer audio spectrum analysis. Once the problem areas have been identified they can be adjusted using a graphic equaliser to level out the frequencies. Bass frequencies, having the most energy, are likely to be the most problematic and blur the audio image significantly.

Increased numbers of audience members will absorb more high frequencies and require the high end to be boosted. Conversely, if the crowd thins out, high frequencies may need to be cut. A sound engineer would be able to make the changes at the mixing desk but if one is not present, a trusted friend in the audience could be called upon to advise the performer of the fluctuations.

The advantages of applying these practices equate to more than just a good sound for its own sake. It also reduces the risk of hearing damage, makes for a more enjoyable event for all, reduces the likelihood of complaints from neighbouring premises and increases the ability of venues to stay within the limits of legal regulations and meet their duty of care obligations to their customers.

The findings regarding concert halls, though subjective, raises a question about the number of speakers acts might consider using. A small venue cannot have the reverberation properties found in a larger space and appreciated by concert goers. A stereo pair require enough volume to be heard at the back of the room. That, of course, means that the volume at the front needs to be quite high. Increasing the number of speakers and spreading them to further points in the room would mean a lower level would be necessary from each speaker to fill the space. For the innovators it would also present an opportunity to experiment with spatial audio. It could add a new dimension and allow the sound to be moved around.

Hearing is so fundamental to us but for the most part, we take it for granted. It is, for the majority of, people a constant. Even when we sleep our hearing is still active. Taking steps to protect it seems like a good thing to do.

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