Acoustics: Win The Battle Before It Begins Part 3 - Sound Quality

AV RoomService, Ltd.
The Science of Perfected Sound

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Again, the title refers to a means to achieve victory by taking proactive steps to prevent a conflict from occurring in the first place. This may involve anticipating and addressing potential challenges or obstacles before they arise or establishing a strong position or advantage early on. The idea is to be so well-prepared and strategic that victory is essentially assured before any actual confrontation takes place.

In Part one and two (Issues 266 and 267) we covered noise control. Before we can address sound quality, noise control measures must be in place. Now that airborne and structureborne noise distractions coming in and going out of our space are mitigated, and the ambient noise floor levels are low enough to hear low-level details, remove distractions and allow wide dynamic range, we can discuss acoustics from a sound quality point of view. At a high level, we are referring to:

1. Equipment set-up and calibration
2. Structural resonances, buzzes and rattles
3. Reverberation times
4. First order reflections
5. Room modes

And at lower levels, we are refereeing to:

1. Good low frequency articulation
2. Tonal balance
3. Linear reverberation times
4. Soundstage imaging, width, depth and height
5. Wide dynamic range
6. Uniformity of sound

We will cover the high-level categories in this issue.

Equipment Set-Up And Calibration

Back in the day, mono was the only game in town. This allowed such easy set up. As soon as stereo was introduced, so were many means of distortions like; phase interference, level mismatches, twice the electronic equipment to go wrong, twice the number of room reflections, even seating locations suddenly became a major issue regarding sound quality. A single loudspeaker can cover the whole space pretty well. However, two or more can only converge at a single point in space and time. Those sitting outside of the "calibrated" zone will be too close to some loudspeakers and too far away from others, and will not hear correct levels or arrival times. There is no way to get around this, however controlled acoustics will make the calibrated area larger from a low frequency, reverberation, and tonal point of view. When I have people over, I give the primary seat to guests and I take the worst seat availalbe.

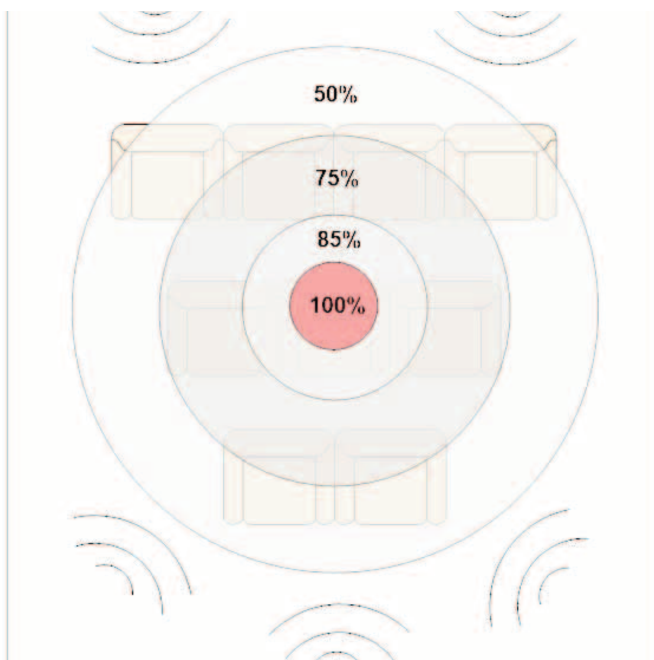
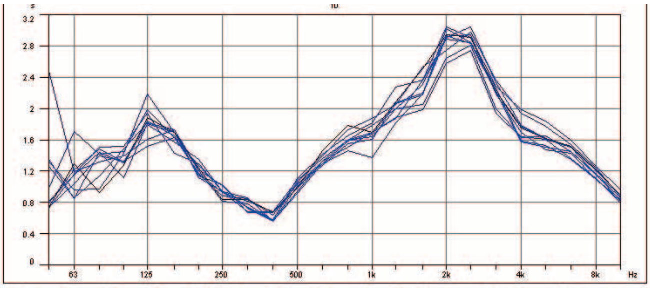


Figure 1. Indicating the approximate sound quality percentage at different seating locations.



Reverberation times (9 positions) in a typical, carpeted media room.

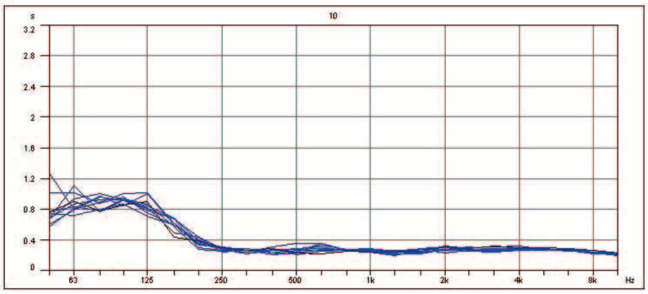


Figure 2. Showing actual measurements of room reverberation times from nine different positions. Each curve is the average of seven measurements.

Set-up means generally physical set-up of the equipment and the listeners in the room. Calibration generally is the electrical configuration of electronics. Either term can be interchangeably used, and/or mean both. Both require tools, instruments, and ears to objectively and subjectively optimize the system. Physically the loudspeakers and listeners must be positioned in the room optimally so that the stereo spread is correct, and that room mode interference is minimized. Loudspeaker obstructions are avoided and symmetry is balanced. Aiming of the loudspeakers for optimal tonality and soundstage, etc. Electronically the configuration of channel assignments, bass management, etc. At this point electrical input/output signal levels should be confirmed, waveform distortion analyzed, channel polarity and each driver phase verified, frequency response, etc. Finally, sound pressure level and delay settings, which may also include equalization. Often the verification steps reveal manufacturing problems that are otherwise missed, resulting in less than optimal performance or even damage.

Structural Resonances, Buzzes And Rattles

Running a tone generator slowly from the lowest frequency the system can produce up into the beginning of the tweeter's range at reference levels can reveal buzzes and rattles in the structure, the furnishings, and/or the loudspeakers. The test requires hearing protection, while still allowing you to hear. Solutions may mean tightening up fastenings, adding felt or rubber to a knick-knack, driver replacement, etc. The best solution is to mechanically isolate the source of vibrations (the loudspeakers, especially subwoofers) with resilient feet like Equipment Vibration Protectors designed for audio equipment. They will not only improve the sound quality by silencing the room from resonances, buzzes and rattles, but will stop structural vibrations from being transferred to adjacent spaces, which may bother other residents.

It is interesting to note how significant structural vibrations are to sound quality. Most people have never experienced a structurally quieted room or realize that there are four signal arrival events in the typical listening space.

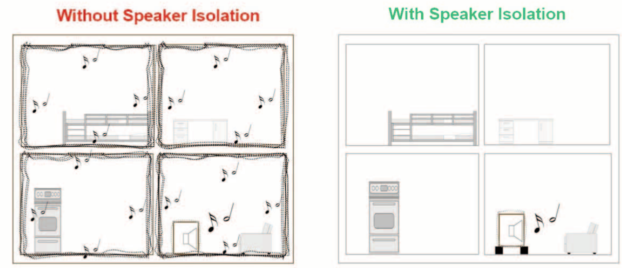


Figure 3. Indicating that when loudspeakers are connected to the structure, the room's walls, floor and ceiling vibrate and playback into the space later in time, and with structural resonances vs. the quiet when decoupled with appropriate isolators.

Listener Arrival #	Vibration Source	Path Medium	Frequency Band	Prevention Methods	Cause	# of Arrivals
1st	Floor	Structurborne	Bass	Mechanical decoupling	Sound energy in materials denser than air travel many times faster (and further)	1
2nd*	Loudspeaker	Airborne	Full	N/A	Direct sound waves from loudspeaker to listener	1
3rd	Walls, floor, ceiling	Specular reflections	Mids & highs	Absorption /Diffusion	Travel distance; from speaker, to surface, to listener	Minimum-6 per speaker
4th	Walls, floor, ceiling, structural cavities	Structurally transferred & re-radiated	Bass & mids	Mechanical decoupling	Stored and released resonant energy, buzzes and rattles	Limitless

Figure 4. Representing the four arrival times of the audio signal in an acoustically uncontrolled room.

Reverberation Times

Reverberation is the decay of sound that bounces off the room's hard surfaces so rapidly that you cannot separate them from each other. Often in acoustics single numbers are used to describe a characteristic. This is never a good idea. It does not tell the story. Single numbers are always derived from a plot curve with many data points representing a range of frequencies, time and/or amplitudes. Reverberation is sound energy reflecting around the hard surfaces too many times and for too long a time. The reverberation of each room is unique, just as someone's voice or fingerprint. The size, shape, construction and furnishings all contribute to the sound. As it impinges on the surfaces, some of the energy is reflected, some absorbed, some transmitted, and some scattered. Uncontrolled reverberation is tonal (see Figure 5), but the primary offenses of uncontrolled reverberation is how it masks low-level details and limits dynamic range. Very reverberant rooms make speech intelligibility difficult. Even in typical rooms the reverberation alters spatial cues, articulation and timbre (see Figure 6 and 7).

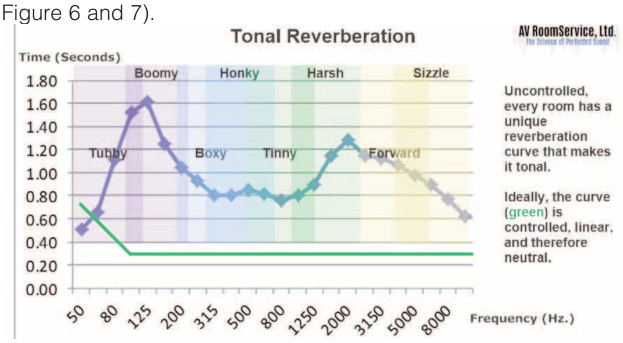


Figure 5. Representing how different decay times at different frequencies cause tonal issues.

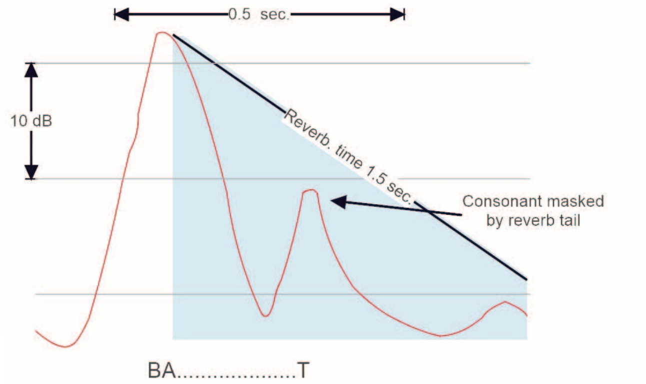


Figure 6. Showing how lingering sound masks new sounds.

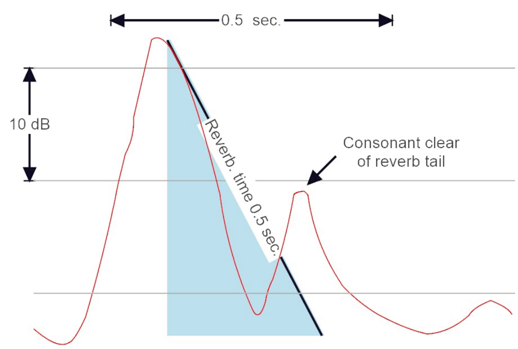


Figure 7. Showing how controlled reverberation times allow details to be heard.

Control of the room's reverberation times is a process, much like a medical condition. When you go to the doctor with a problem, you explain what's wrong. They run tests, analyze the results and come up with a prescription to counter the problem. With an existing room, you test it with electronic instruments and then analyze the results to learn the acoustical characteristics of the room. You then computer model counter-attack solutions for the best prescription to correct the problems. Once applied, you typically test again to confirm the formula worked as expected, or that it needs to be adjusted. The prescription includes the right acoustical products, in the right locations, in the right quantities. This same scientific approach is done for many other acoustical problems. What are the existing conditions, what are the goals, what are the constraints, what's the best prescription.

The computer modeling incorporates finite-element analysis with product material data from standard laboratory test reports. These test standards include material absorption, transmission, diffusion, wave propagation, sound power, intensity, etc., and they are measured in the time, energy, and frequency domains. The goal is to make the room sonically neutral so that it doesn't' add or subtract from the recorded signal being played back. With reverberation, this means the decay times should fall within 0.25 – 0.4 seconds from 125 Hz. on up, with a slightly rising decay to around 0.7 seconds as we go down in frequency (see green curve in Figure 5).

First Order Reflections

In the typical room, there are six surfaces: four walls, a ceiling, and a floor. Each loudspeaker will reflect off each of them, then move on to the next surface, bounce off of it and so on in geometric relationships between the loudspeaker, the boundary, and the listener. The reflections interfere with the initial direct sound of the signal from the loudspeaker to your ear. These reflections arrive to the listener later in time, after the original signal has stopped, and they run into the oncoming new sounds causing constructive and destructive interference. Each successive bounce has less energy as it is absorbed by the air and the materials it encounters. This is why controlling the first reflections are so important to sound quality. Mitigate the first reflections and you mitigate the train of reflections that follow. The first and earliest reflections are the most problematic in most instances, as they have the most energy. However, late arrivals, like returns from an opened adjacent room can also be distracting.

The reflections can be controlled with absorbers or diffusers. The choice will be determined by the existing reverberation times of the room. It is very easy to have too much absorption, while it is difficult to have too much diffusion once the reverberation times are controlled. The idea is to reduce the hard specular reflection by either absorbing it (converting it to heat) or by scattering it back into the room. Scattering it will attenuate, dilute, and spread the signal out into the space. We are mainly concerned with about 500 Hz. and up. Lower frequencies, due to their wavelengths, would be very difficult to address with absorbers or diffusers. Note also that number-theory diffusers are not going to be applicable on the side walls, ceiling or floor, as they cast a shadow on themselves, and typically only address very high frequencies. Such diffusers are only effective when placed on the front or rear wall for first order reflections. Geometric diffusers are the answer, especially Polycylindrical diffusers, as they are effective over a broad frequency range, and a broad angle range.

Room Modes

Room modes are standing waves that develop as a result of the room's dimensions and construction. Standing waves (modal resonances) occur when wavelengths match parallel boundary dimensions. This reflected energy occurs for the room, height, length, width axis and can also include tangential and oblique modes. The lowest frequency of which is when the longest spacing equals a half-wavelength. The boundary must be substantial enough in mass and stiffness to reflect the energy. We are typically talking about frequencies below 300 Hz. Standing waves cause extreme high and low pressure points in the room. They are often as much as 25-30 dB swings. When standing waves are too far apart from each other, or when they are too close, they will draw attention to themselves in the sound level being too high or too low, depending on the frequency and location of the listener.

There are five ways to control room modes passively:

1. Build a room whose dimensions distribute the modes evenly across the low frequency bandwidth.
2. Use construction materials and methods that allow flexure to help absorb them.
3. Place speakers out of their way.
4. Place listeners out of their way.
5. Incorporate the right acoustical treatments, at the right locations, at the right quantities.

As you can imagine, room modes are difficult to control, as their wavelengths and energies are very large. They are often the first and most noticeable sound quality attribute, or lack there of. In part four we will dive a bit deeper into lower levels of the whats and whys involved in sound quality for a good cinema experience. All designed so that you win the battle before it begins. WSR

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