

LeadingEdge Systematic Approach

Room Acoustic Principles - Paper One

The Standing Wave Problem

Sound quality problems caused by poor room acoustics.

We all recognise that room acoustics can cause sound quality problems. But often the issues are not clearly described or discussed. Here we will cover some important considerations and principles of room acoustics problems.

Treating your room should not be done in isolation from all the other system building considerations. Your thoughts about room acoustics treatment should be in conjunction with your requirements for mains, supports, system electronics, speakers and cables etc. None of these should be dealt with in isolation, and with regards to room acoustics it's particularly important to be aware of some of the interactive nature of room acoustics, and other systematic faults. For example, a boomy bass could be caused by a room mode, but equally it could be caused by bass feedback from a wall and up into your system through the mains leads. If it's your mains cables feeding back vibration that's the dominant problem, spending money on room treatment may not correctly resolve the issue.

Room acoustics problems can be grouped into the following categories.

1. Air mass problems:

- Standing waves with sound pressure peaks and suck-outs (and associated velocity peaks)
- Velocity generated intermodulation

2. Reflection problems

- Unwanted reflected signals at the listening position
- Raised reverberant background noise floor

The behavior of a room's air mass is the most important consideration with room treatment. A significant air mass problem is a fundamental destroyer of performance - uncontrolled room modes produce associated velocity intermodulation, which damages every aspect of musical reproduction. This is the most significant problem in room acoustics and should be the priority target in your room treatment approach.

Once air mass behavior is correctly controlled, further treatment can be applied to deal with residual reflection problems.

In this paper we cover the important principles and the application of LeadingEdge micro-perforation products to the standing wave problem.

The LeadingEdge Acoustic Panels

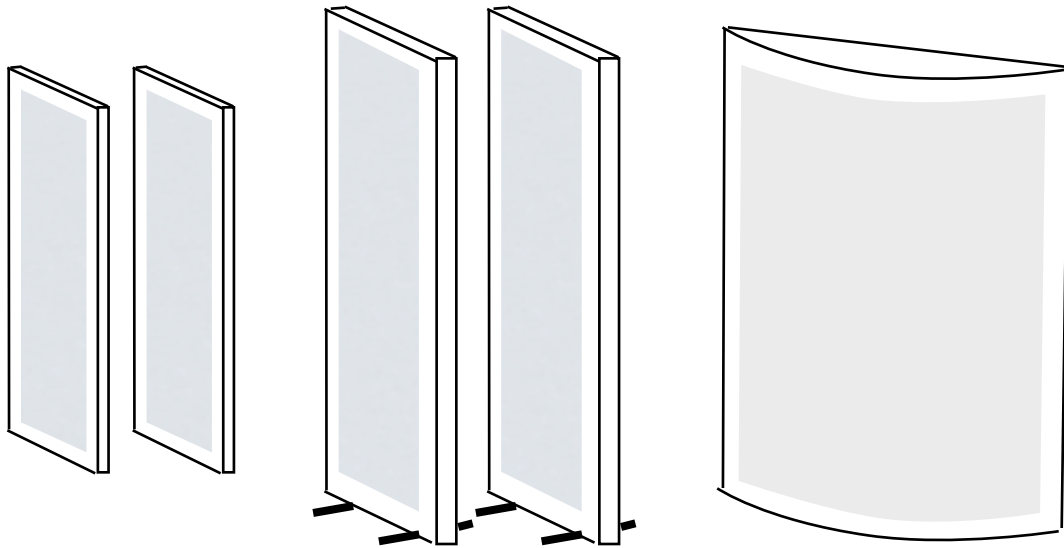
The LeadingEdge acoustic panels fall within two technology groups:

In this paper we will be examining the problem of standing waves and the use of the micro-perforation panels to treat these problems.

The issue of acoustic reflections and the use of the spline diffusers will be discussed in Room Acoustic Principles – Paper Two

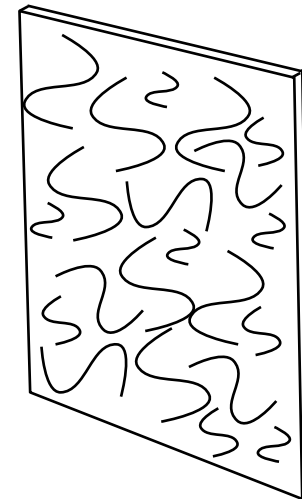
1.

Panels using micro-perforation technology. These come in both flat panels and curved 'D' panels.



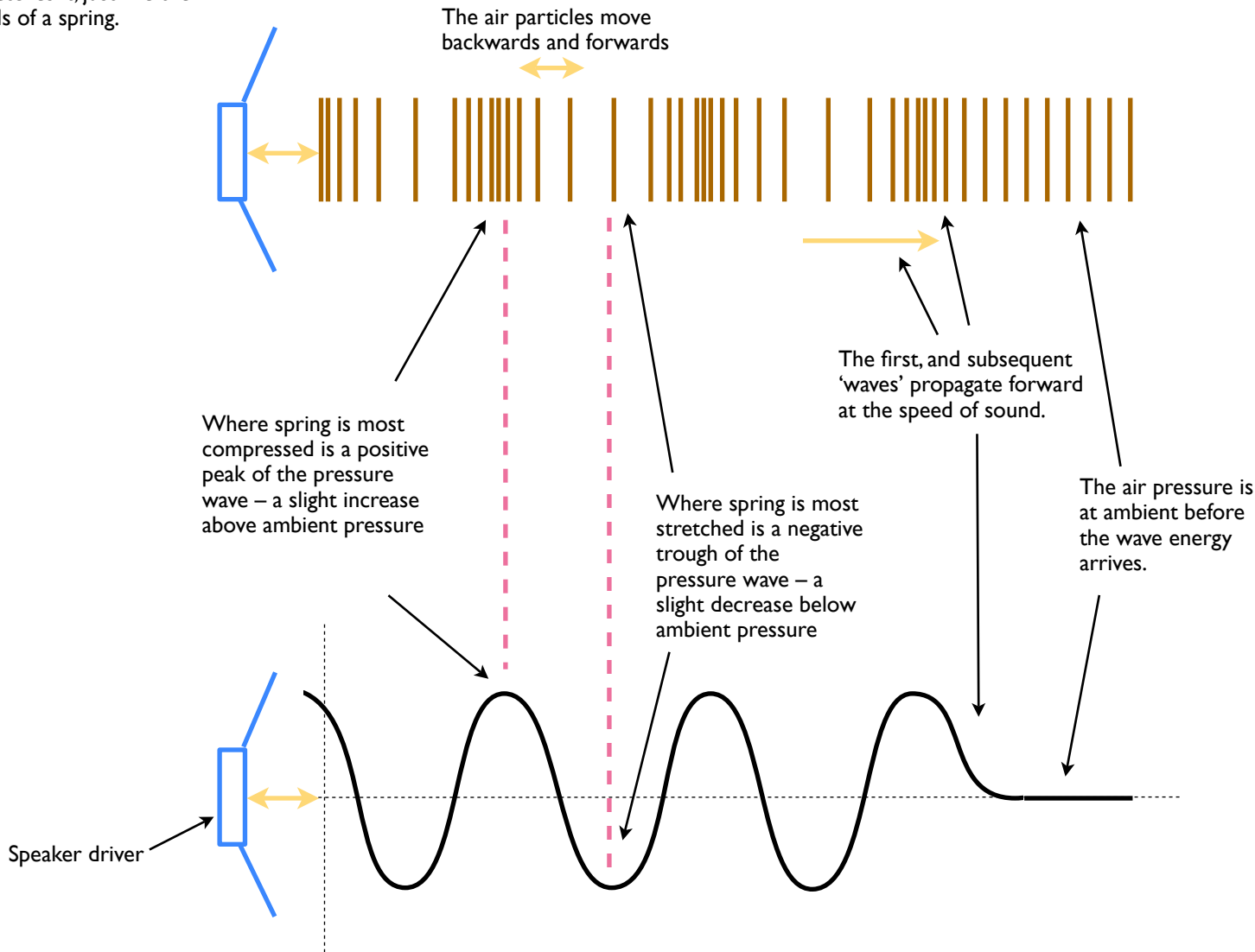
2.

Three-dimensional diffusers based on spline mathematics.



Essential Theory - Traveling Waves and Standing Waves

1. The air around us behaves like a spring. It's a compressible gas with mass. So our moving driver compresses and stretches it, just like the coils of a spring.



2. Note that it is the wave front, and subsequent waves, that travel at the speed of sound, NOT the air particles, they only travel a few millimeters per second - even when its 'trouser flapping' loud. Normally the particle velocities are very low.

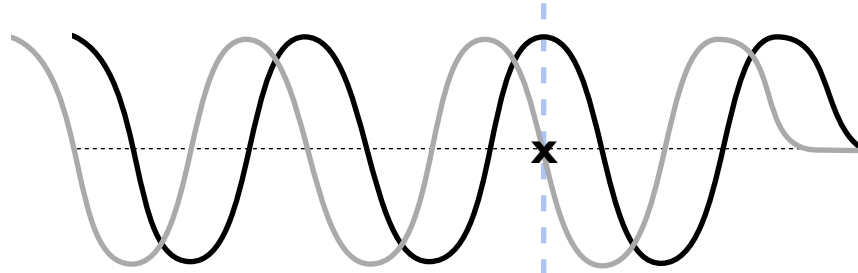
The pressure component of sound is referred to by scientists as a 'scalar', which means it only has a single parameter to define it. Pressure has a magnitude but no direction. Sound pressure level is therefore the variation above and below atmospheric pressure.

The particle velocity component of sound is a vector and has two parameters to define it. For sound it has speed and direction.

A good analogy of how sound behaves is to imagine a long row of railway carriages on a track. Shunt the carriage at the back and they each knock into the next one in front, and the shunt 'wave' rapidly moves up the line of carriages to the front - but the carriages themselves hardly moved at all in the process.

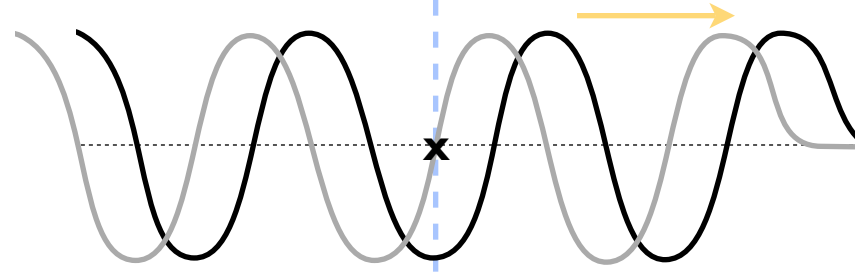
3. Here in this diagram we represent the air mass behavior by plotting relative pressure on a graph. This is the sort of representation we are used to seeing for sound waves. **But take care to remember back to the spring-like behavior, because a sine wave gives no real impression of the 'mass' and 'springiness' of air.**

1. If we now also plot the particle velocity of the traveling wave (grey line), we see that it lags the pressure wave by 90°. When the pressure is at its maximum or minimum, the particle velocity is at zero,



2. As the wave travels past a fixed point (point X), the pressure part goes positive and negative, and the velocity goes positive and negative, but 90° out of phase.

Remember that the pressure part does not have direction, but the velocity part does. The velocity will have a value and a direction. The particles move forward, in the direction of the wave, then they stop, and **then they go backwards in the opposite direction to the wave.**



3. Up to now we have been talking about traveling waves. And traveling waves exist when they are in free space. Outside, in the open air, all waves will be traveling waves.

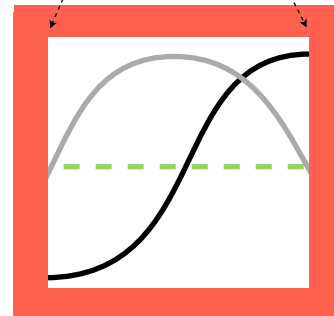
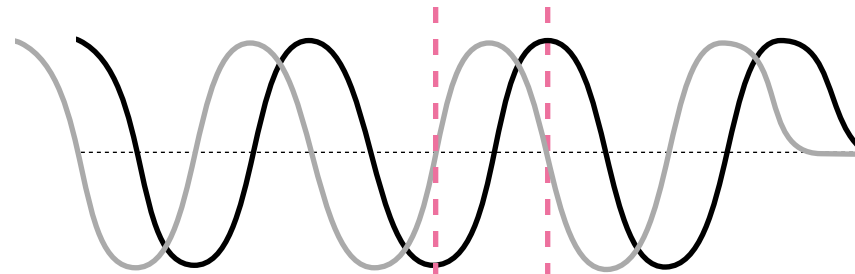
So now on our diagram, let's draw 2 red dotted lines. One is at the maximum negative pressure value, and one is at the maximum positive pressure value.

And see how at each red line the velocity is zero, and it's at its maximum half way between the two points.

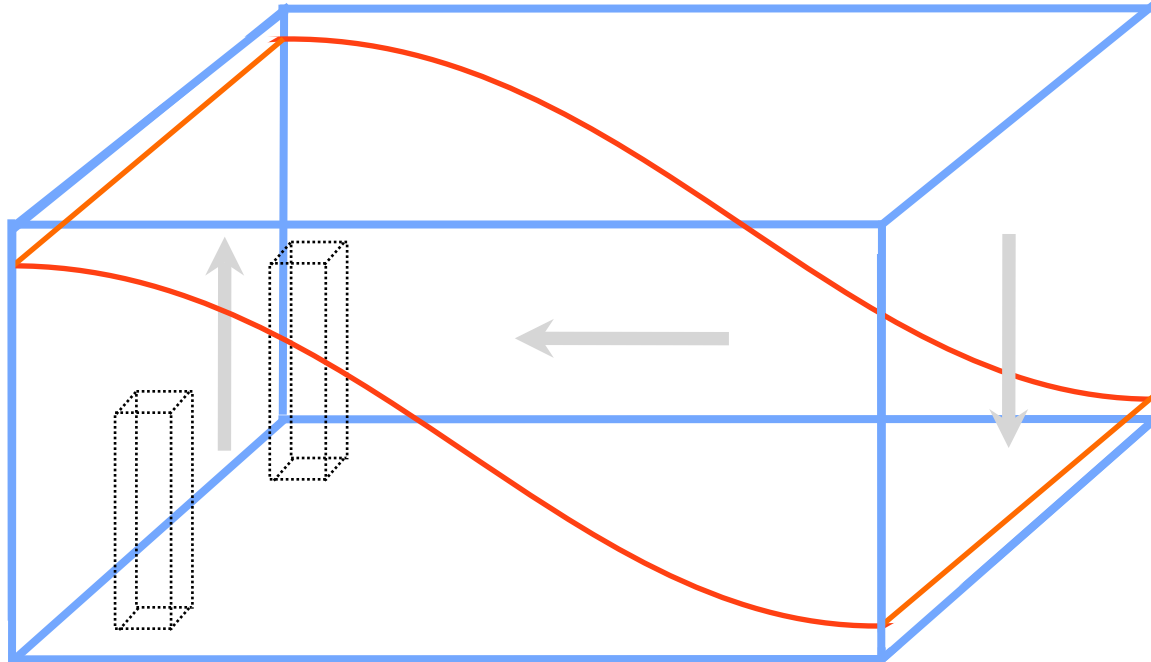
At high frequencies, these 2 lines will be quite close - maybe a few centimeters - it's half the wavelength, of course. But down at bass frequencies, this distance becomes the same order as the dimensions of our room.

And when things change, is when we 'trap' or constrain sound inside a closed box.

We can now carry this knowledge into the considerations for a listening room on the next page.

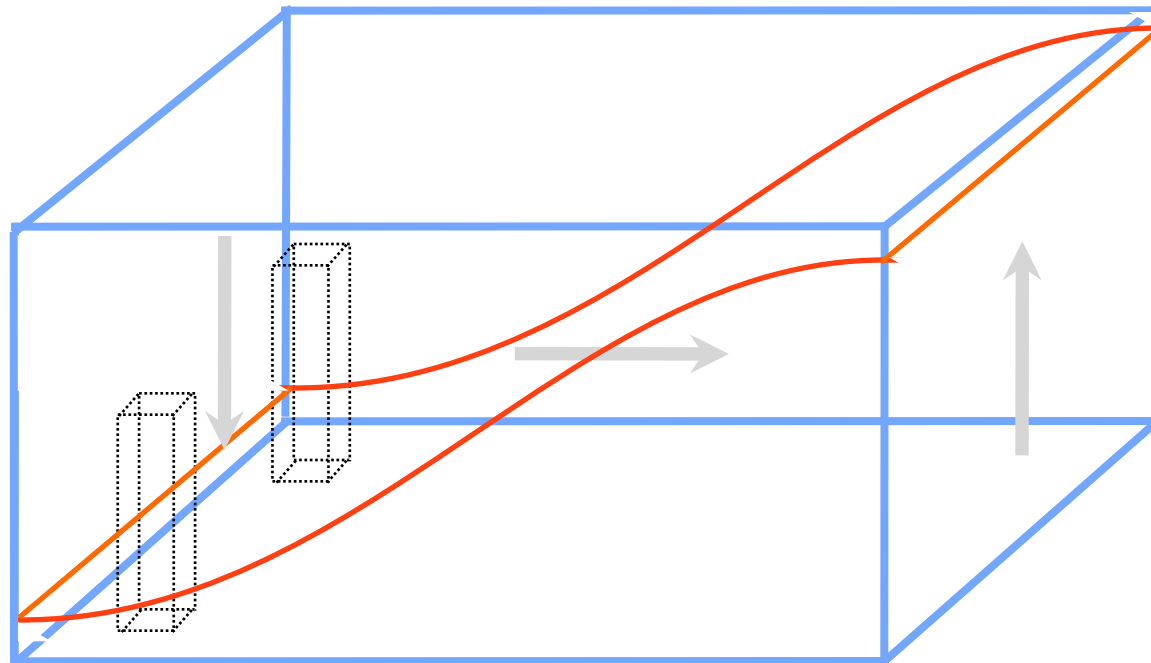


Standing waves in our listening room

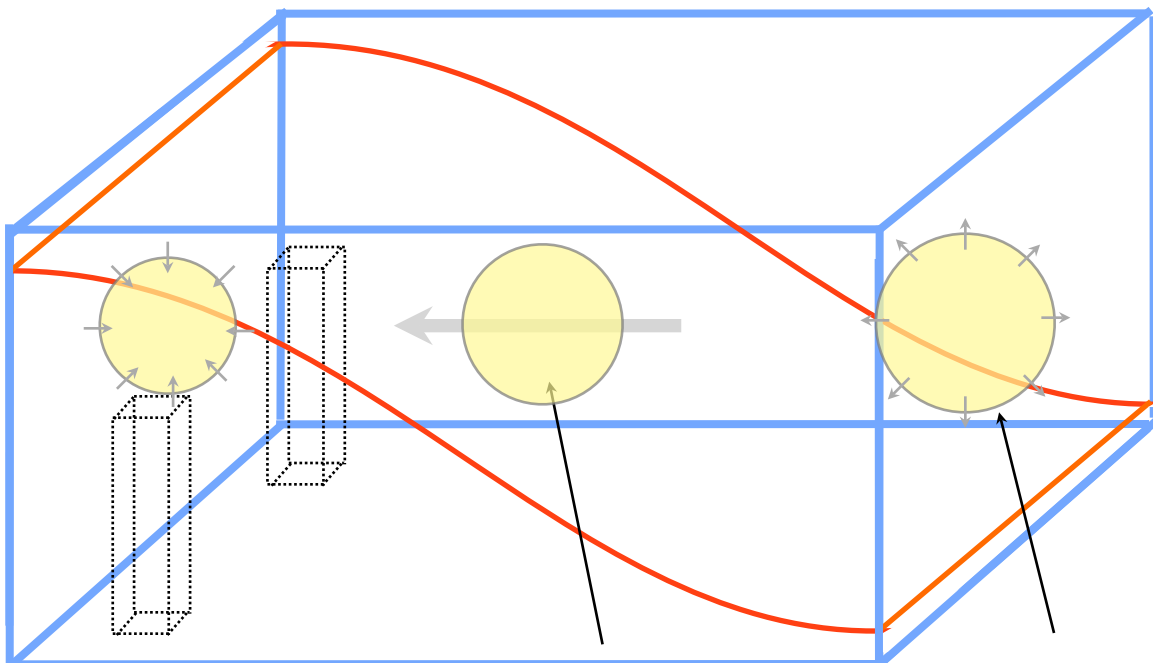


1. Now we can examine in more detail the acoustic behavior in a listening room. In this diagram our room is energized by a pair of speakers positioned symmetrically on the short wall

When the speakers generate bass we stimulate the room, and when resonating at the room's fundamental frequency (a standing wave) the air pressure goes positive and then negative at each end of the room as the air mass 'springs' from one end to the other. Half way along the length of the room, the sound wave is working completely in the velocity mode - there is no pressure change here, and we cannot hear the sound at this point. We tend to assume there is no bass problem here, because we cannot hear it at this location. But it is there of course, in its velocity component, transmitting its energy to the other end of the room, where we can hear it again!

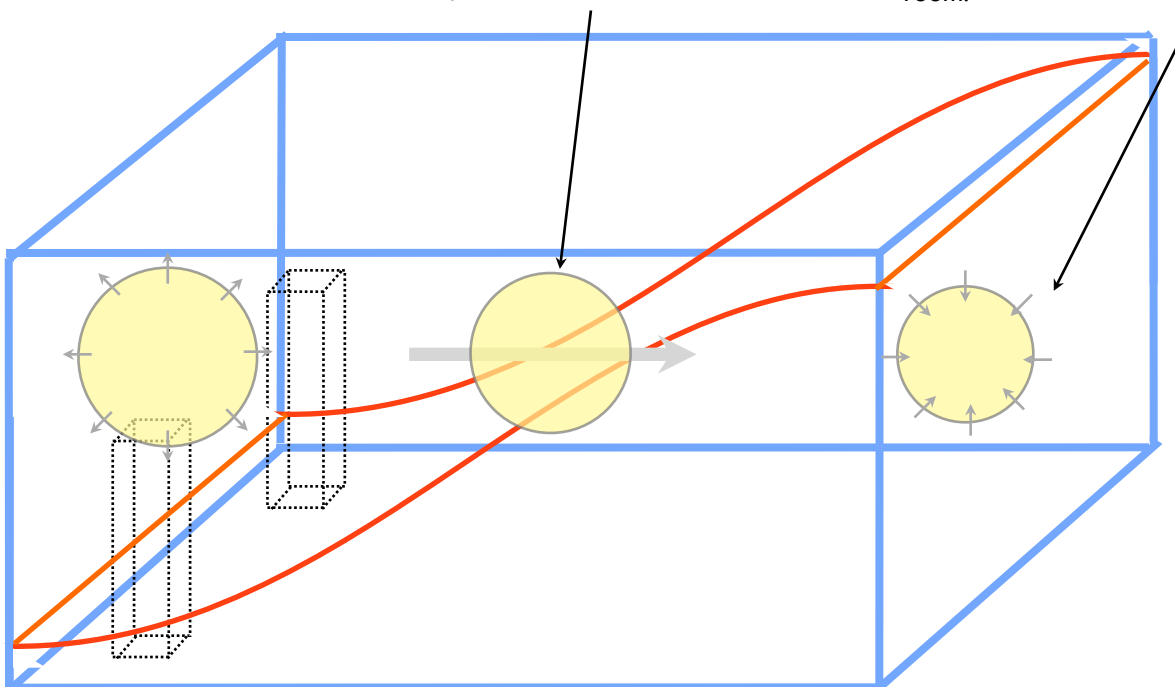


Pressure, Velocity and Room Gain



There is no pressure change here - so we don't hear any sound. The wave is purely in its velocity mode. The air's energy is in the form of momentum here and the pressure remains constant.

The air is literally 'squeezed and let go' by the standing wave. We hear the rise and fall in pressure at both ends of the room.



1. In modern acoustics, products like pressure/velocity microphones (see products such as Microflown Technologies) have 3 orthogonal acoustic particle velocity sensors, and one pressure microphone mounted on a single sensor head. This is the only way to get a true representation of acoustics at any specific point.

In our diagrams here, if you were to use a pressure/velocity microphone you would measure all the acoustic energy as purely a pressure change at each end of the room, with no velocity component at all. In the middle of the room you would not see any energy as pressure change at all - the energy would be completely in the velocity domain. And of course, the microphone is directional with its velocity measurement, and by resolving the readings from all three axis, would show that the direction was longitudinal down the room.

Furthermore, when the air is moving back and forth in this velocity 'zone', the movement will move all the higher frequency traveling waves back and forth too. This causes significant intermodulation of all the musical bandwidth, blurring image and detail and adding coloration to tonal content. More of this later!

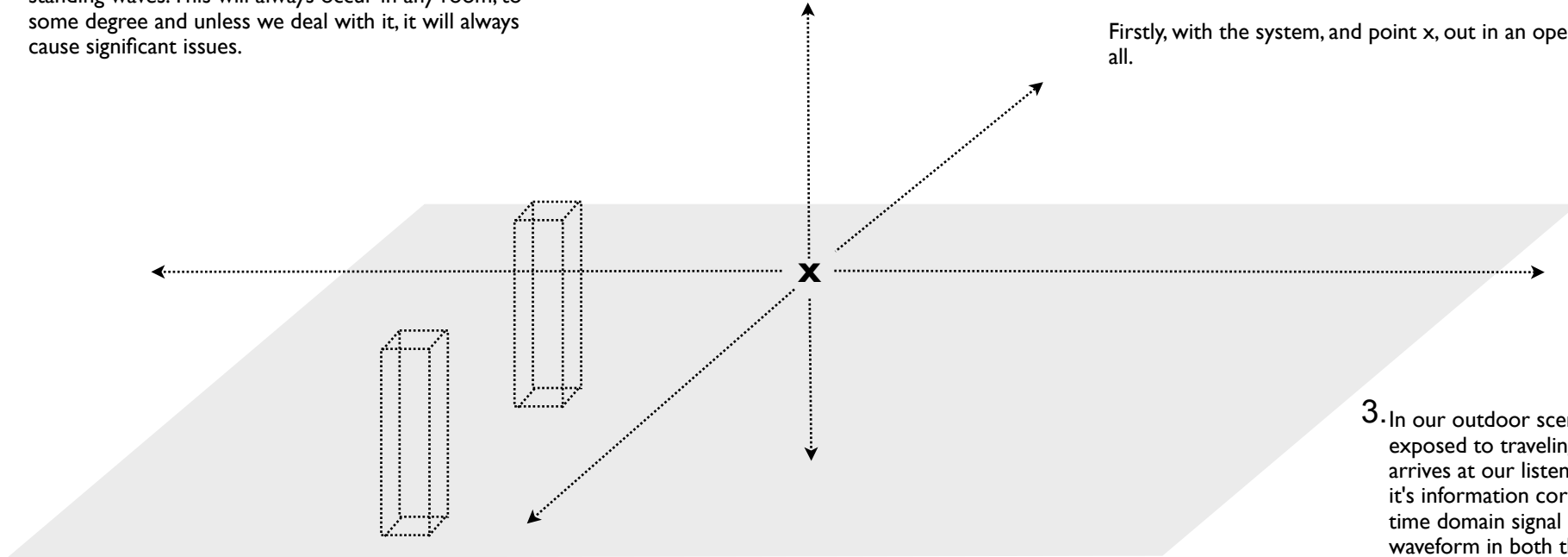
The human ear is of course a pressure sensor, it does not detect acoustic energy in the velocity domain.

2. The next part of the problem is room gain.

The speakers keep stimulating the resonant modes, and because the air in our room has mass, and is springy, it gains momentum back and forth, **increasing the particle velocity at the centre of the room, and increasing the pressure changes at the ends of the room,**

This increase is a form of stored energy, and it's level is now much too high, and retained for too long, in relation to the intended levels of music on the recording.

1. If we have some standing waves, our airmass is being moved not only by stimulus from the loudspeakers, but also by the build-up of our 'over-exaggerated' resonant standing waves. This will always occur in any room, to some degree and unless we deal with it, it will always cause significant issues.



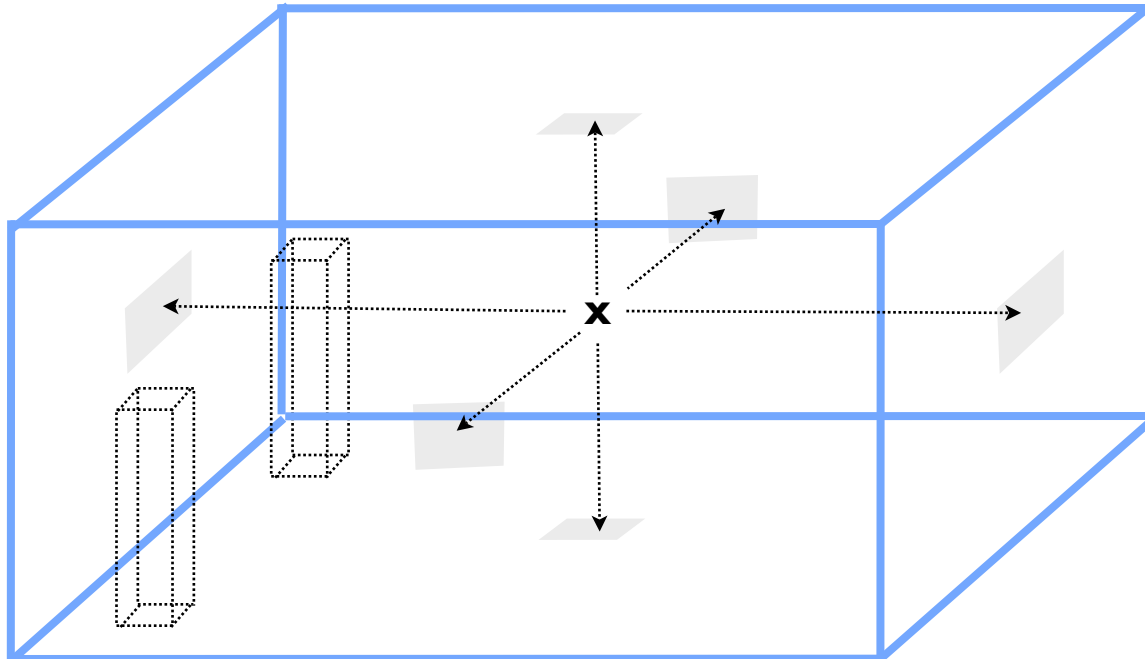
2. So why, if we cannot hear in the velocity domain, is this exaggerated velocity mode such a problem? Lets consider what happens at point x (our listening position if you like), in the velocity domain - in 2 different scenarios.

Firstly, with the system, and point x, out in an open field, with no walls at all.

3. In our outdoor scenario we are only exposed to traveling waves. The music arrives at our listening position with all it's information correctly in place. It is a time domain signal of course, a complex waveform in both the pressure domain and the velocity domain. If we were to measure at this place in first the pressure domain and then the velocity domain (with a particle velocity sensor) we would see the same waveform shape. The pressure would oscillate above and below the ambient pressure and the particle velocity would oscillate forward and backward, about the stationary position. The only significant difference between the two is that the information is phase shifted by 90 degrees.

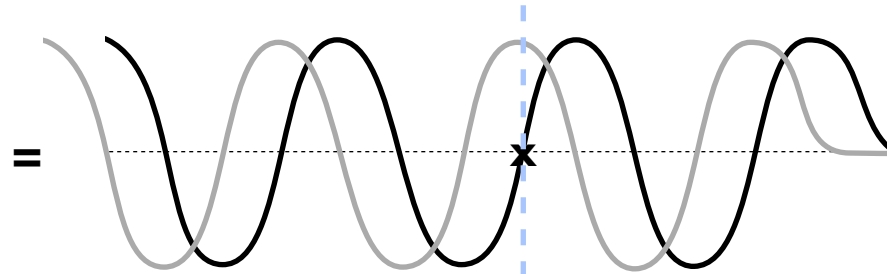
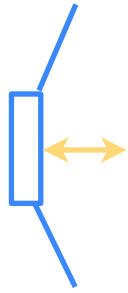
4. But if we now enclose our listening space within walls and a ceiling, we introduce our two problematic effects - the reflection of our traveling waves above the Schroeder* frequency, and the buildup of standing waves below the Schroeder frequency.

We'll deal with the reflection problem in another paper, but let us consider the effect of the standing waves in our room at point x in more detail.

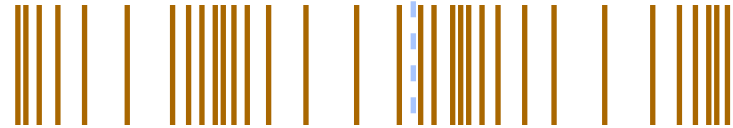


* Schroeder frequency is the frequency below which the room is capable of creating standing waves.

A

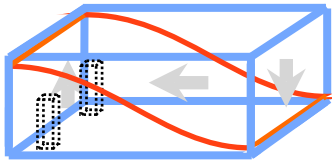


1. So this waveform represents the musical signal we want to hear. And it shows both the velocity and the pressure waveforms. Okay, its a very simplified sine wave - in reality it will be a very random and complex signal



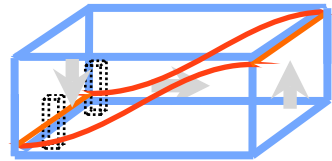
Here we represent the same thing in the form of the 'spring'. And remember, this is a much truer representation of the behavior of the air than our sine wave plots.

B



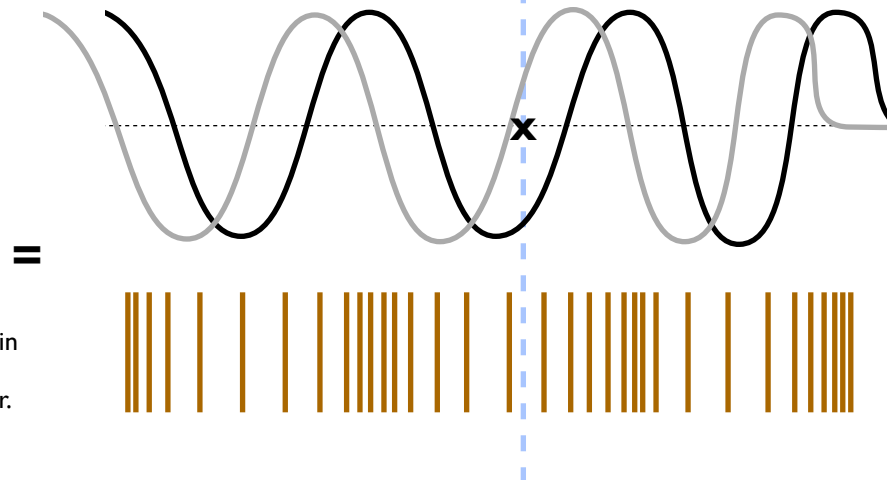
And here we represent the standing wave that has built up in our room - with its excessive 'springing' from one end of the room to the other. We can see how the pressure goes high and low at each end of the room, but also that the pressure from this wave remains constant at point X, because the lines remain the same distance apart.

C



But there is high particle velocity here of course. See the green line (9th from the left), which moves a considerable distance in this representation.

A + C



What happens is the music velocity wave and standing velocity wave will combine into one 'summed' waveform. And because that happens, the pressure part of the traveling wave (the part we here) will be significantly modulated by the presence of the standing wave.

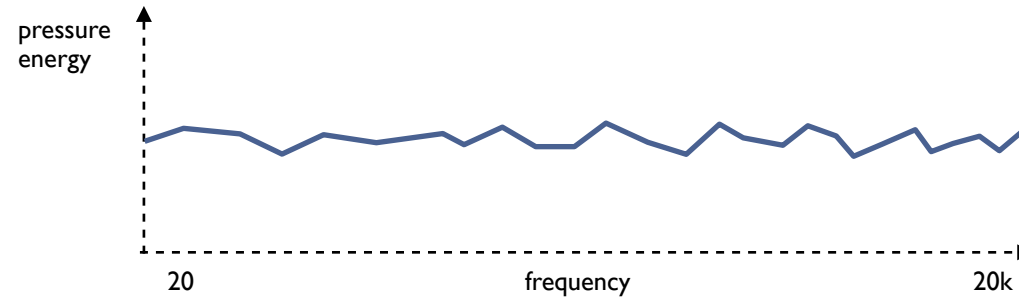
It's like mounting your tweeter on the face of a sub-woofer driver going forwards and backwards 30mm at 30Hz! That would be crazy, and would obviously throw out all the timing and phase information, as well as distorting all the tonal information.

This is what we call Velocity Modulation

2. At point X now, what we hear at that point in time is significantly different from the intended musical waveform from the speaker. And of course, half a cycle of the standing wave later, we would get A + B (not shown).

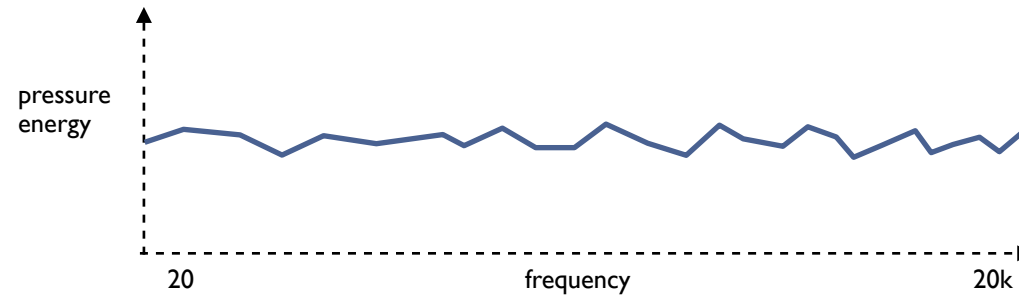
Looking at this in the frequency domain

1. Take a snapshot of our musical signal in the open air at point X, and plot its frequency content in the pressure domain. Inside our room, at point X, without any intermodulation from standing waves (or reflected traveling waves), this would be the signal we would wish to hear - the same as our signal outside.



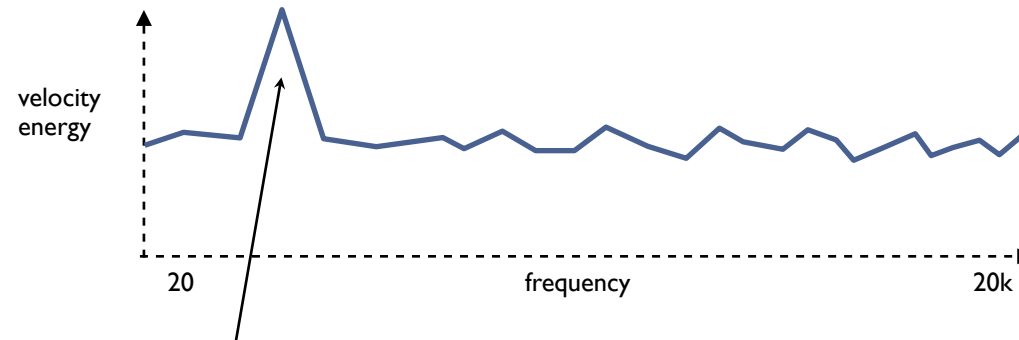
Pressure energy plot – point X – outside.

2. Now, even though we know there is a significant velocity component at point X inside our room from our standing wave, if we just measure in the pressure domain, we won't see it. We also won't see its energy directly - but we will hear the damage it's doing to our music because of all the intermodulation and phase shifting.



Pressure energy plot – point X – inside.

3. But if we now plot velocity energy, we are going to see a big velocity energy peak at our room's resonant frequency.



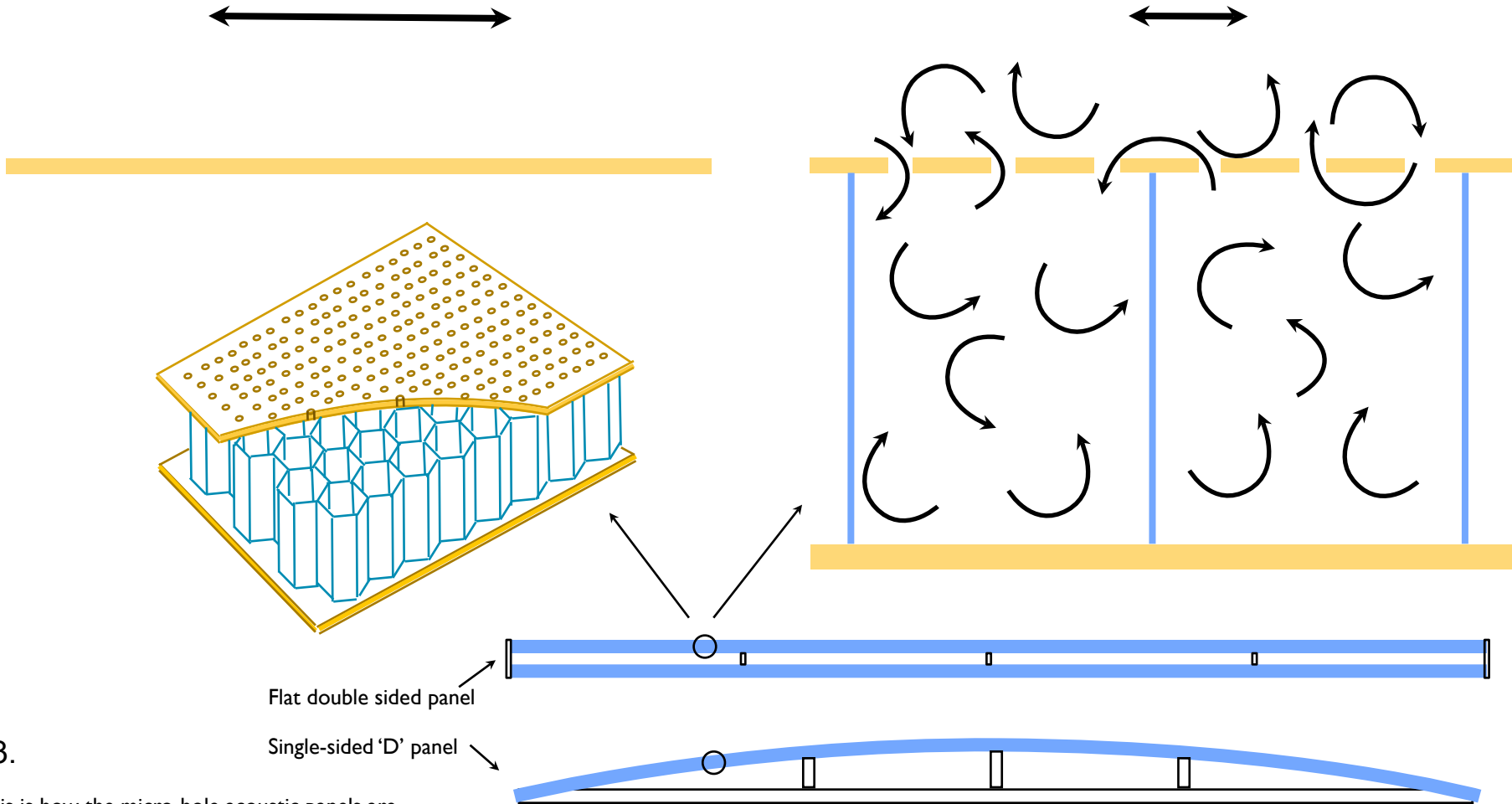
Velocity energy plot – point X – inside.

This standing wave energy is high level and it continues for long periods of time because the room is 'ringing' at its resonant frequency.

Principles of micro-perforation panels.

1. In free space we have seen how our acoustic energy moves back and forward in the velocity domain completely unimpeded. Simple flat surfaces, even if covered with acoustic foam ect. have no significant effect.

2. In the vicinity of the micro-hole surface, as the velocity component builds, there is a corresponding rise in aerodynamic drag, absorbing energy from the velocity part of the wave. This type of design is very effective at creating large values of drag as the velocity increases.



3.

Flat double sided panel

Single-sided 'D' panel

This is how the micro-hole acoustic panels are constructed internally. They work in a completely different way to foam, and are far more effective than foam, therefore requiring less surface area in a room to have a great effect.

These panels are used on the underside of the platforms, on the mini-panels and on the large flat and 'D' panels

The perforations, and the cells below, create lots of little turbulent 'eddys' as the sound passes over the surface in the velocity part of the wave - adding a lot of drag which stops the wave. This is known as a viscous loss technique.

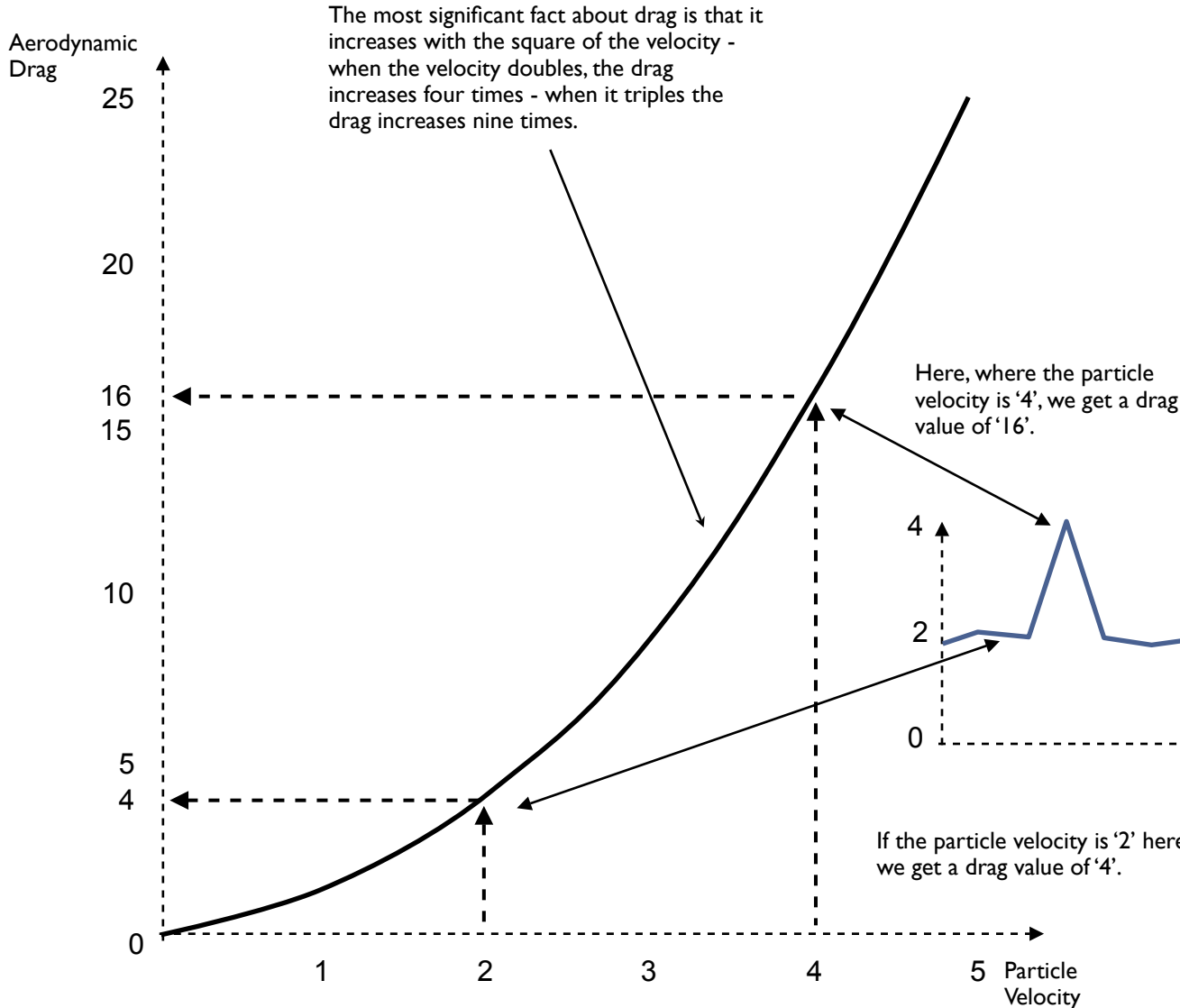
Because of the rotating eddies in the cells below, the air literally blows and sucks through the holes in a random way, but by greater amounts as the local air velocity increases. thus increasing the amount of turbulence over the surface.

Aerodynamic drag

1. Aerodynamic drag is the resistance to airflow produced by a surface, object or structure. Objects that require to pass through the air easily and at speed need to be slick or 'aerodynamic', otherwise the resistance to their movement is unacceptably high. The sleek design of an aircraft is the obvious example, and any significant roughness or protrusion leads to increased drag which slows the aircraft, or requires more power to sustain the same speed.

2. The design of the micro-hole surface, and the honeycomb behind it, is based on the design for linings of jet engine intakes. This very precisely mathematically designed structure produces very high drag levels to the velocity part of sound waves.

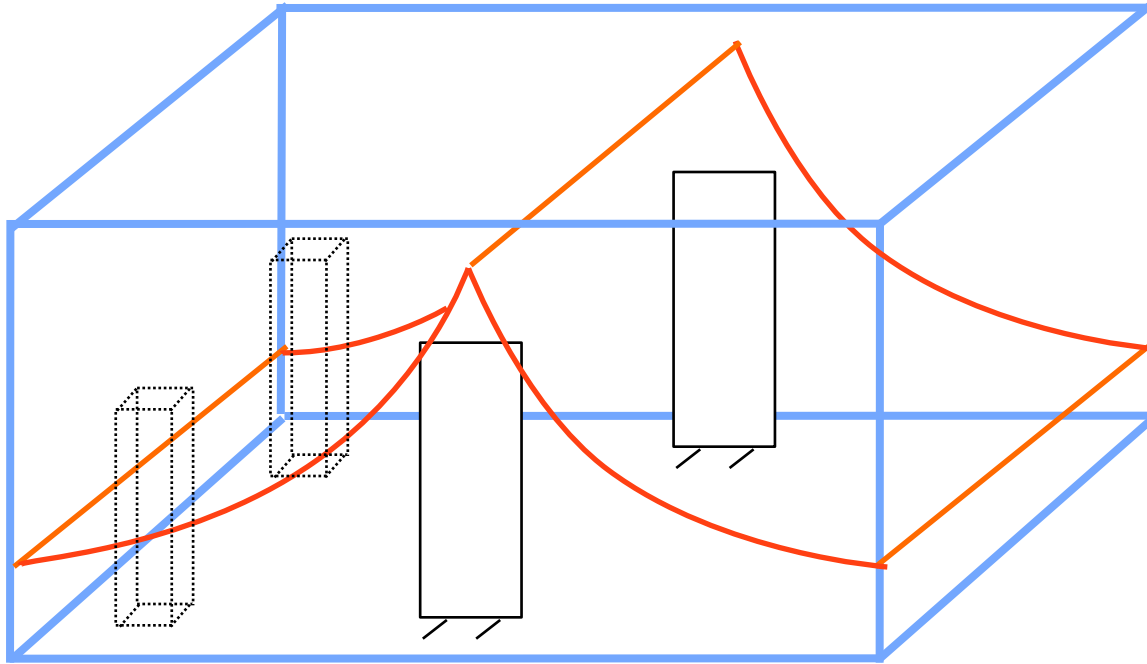
Technology is the same as used on the inside of jet engine intakes to lower compressor noise.



3. So our micro-hole panels are in essence responsive to the levels of particle velocity in our room. The amount of energy removed by drag is proportional to the square of the particle velocity.

Also, the desired music signal spectrum is constantly varying, and does not remain the same for any significant period of time. But our standing wave builds up into a large oscillation over quite long time periods, repeatedly going back and forth over the surface of the panel, so the panel's drag repeatedly dampens the movement of this wave on each oscillation.

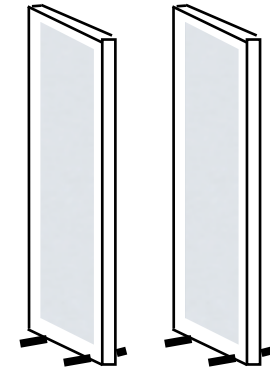
Examples of treating longitudinal and transverse standing waves with micro-perforation panels



1. When we consider our listening room now, we can clearly understand that the velocity part of a longitudinal standing waves is at it's peak half way down the length of the room.

So with a pair of acoustic panels we can treat this problem by positioning them at the velocity peak - half way down the long side walls.

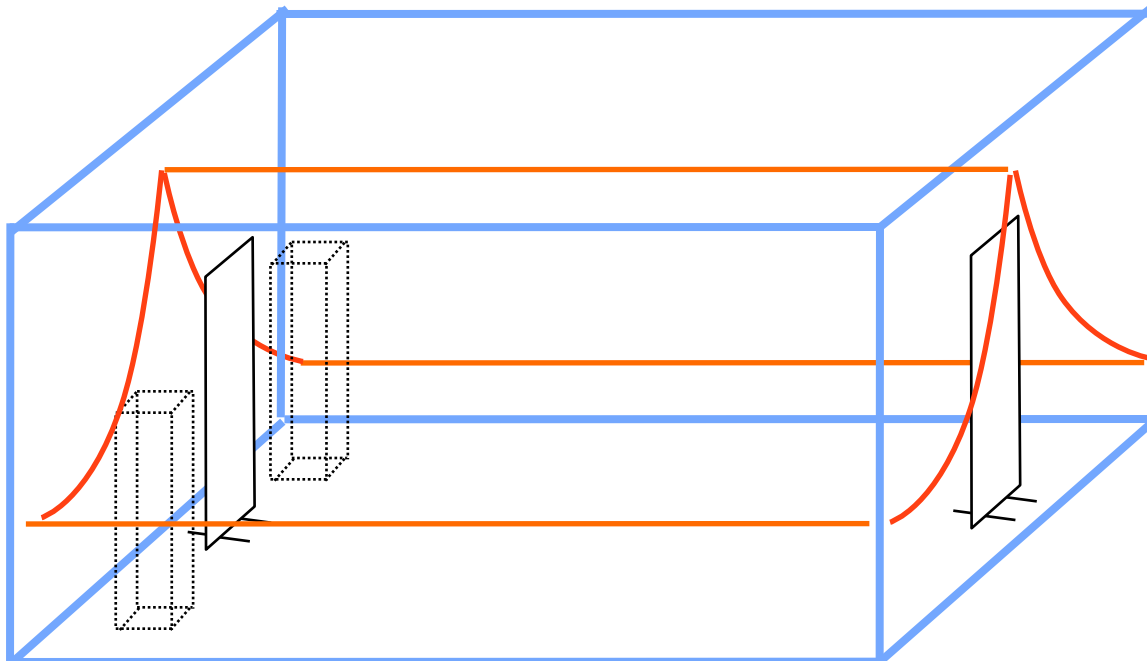
Here we show a pair of double-sided flat panels that are free-standing and stood about 2 feet out from the side walls. This way, the standing wave passes both sides of the panel, so the panel's surface area on both sides is fully effective.



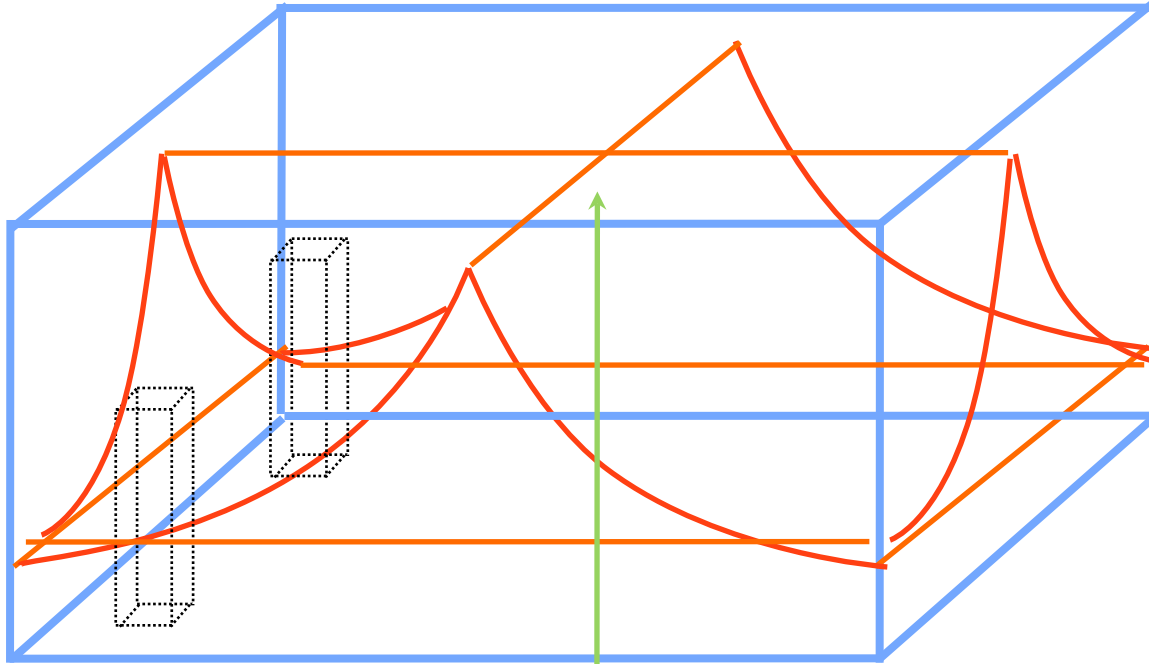
2. And also we consider the transverse standing wave. In the same way that a longitudinal standing wave causes velocity intermodulation in the centre of the room, so does the transverse wave. The transverse wave will cause a left/right movement of all the musical information, again causing blurring of image and smearing of timing.

So with a pair of acoustic panels we can treat this problem by positioning them at the transverse velocity peak - half way down the shorter end walls.

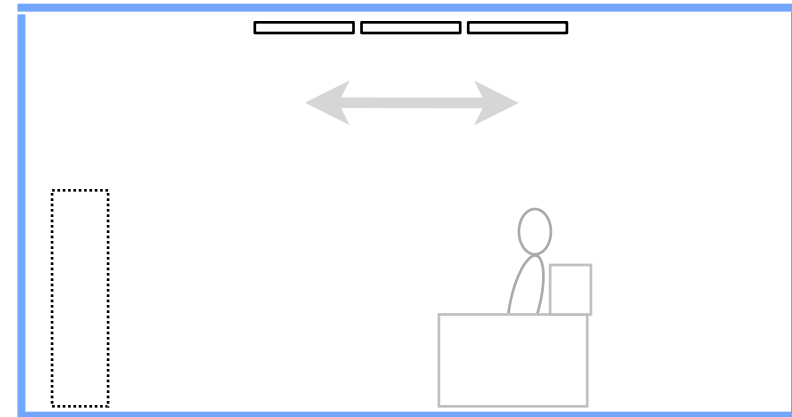
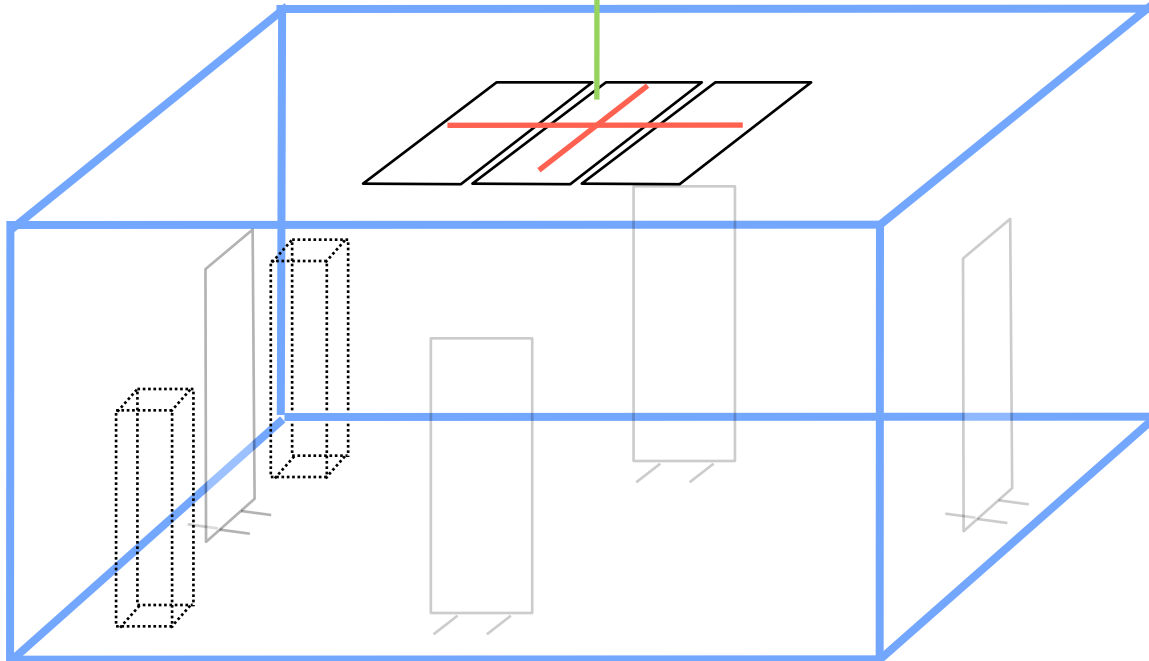
Here we show a pair of double-sided panels that are free-standing and stood about 2 feet out from the end walls. Again, the standing wave passes both sides of the panel, so the panel's surface area on both sides is fully effective.



Examples of treating longitudinal and transverse standing waves with micro-perforation panels



1. And of course, we can treat both standing waves with panels along both the long and short walls. This method gives excellent audio quality plus the flexibility of the mobile panels - they can be positioned optimally for listening, but maybe put back to the walls, or even put away, when the room is used for other activities.
2. Alternatively, it is very effective to use single-sided panels mounted on the ceiling as shown. When positioned together in the centre of the ceiling, the panels work both on the longitudinal and transverse standing wave.



IMPORTANT

The suggestions shown here are just examples to describe the principles of the treatment of standing waves. For specific applications and recommendations for different room sizes, see the configuration documentation.