Essential Elements For Designing Acoustically High Performance Spaces

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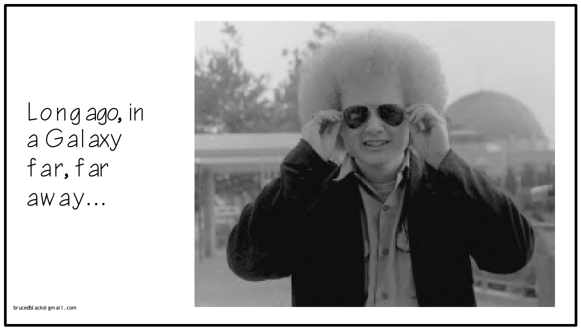

Hello, I'm Bruce Black.

My audio career began many years past, in a distant time and a distant place. And like so many others, it started with mixing live sound for local bands and musical theater. Over time I worked up to bigger acts and bigger venues.

From there I moved to live recording with a remote truck I built, and then into broadcast. Seeking more consistent employment, I shifted to the hardware side, eventually working for the renowned Deane Jensen.

I then started Black Audio Devices, selling mic and boom stand parts and other things I invented. In this picture you can see me modeling the portable personal urban noise absorbing device I created.

Finally, I moved into post production sound engineering, as both a staff and freelance engineer. I've now spent over 25 years working for such companies as Skywalker Sound, DreamWorks, the Academy of Motion Picture Arts and Sciences, and others.

During that time, the acoustical problems often ended up in my lap. The information available to me to solve them was basically hearsay, guesses, and "secret mystical alchemy". This made fixing problems very difficult, and designing good acoustical spaces a hit or miss affair.

I instinctively felt that acoustics was pure science, with no secrets or obscure, dubious sorcery, and that it was possible to create successful acoustical spaces consistently. I set out to learn all about this intriguing subject, and ended up reading and rereading many books by such authorities as Everest, Salter, Long, Beranek, and others.

This led to developing my own technique for designing rooms that has proven to be consistently successful. I have created critical listening spaces, provided solutions for existing room's problems, and consulted for the likes of Sony Pictures, Technicolor, iHeart Radio, and Simpsons creator Matt Groening, as well as for post production legends like rerecording mixer Paul Massey, and music mixer Bruce Botnick.

I have distilled this technique down to 9 Essential Elements, which I would like to share with you now, to help with your own studio build projects.

I have been a member of the Audio Engineering Society for over 33 years, the Academy of Motion Picture Arts and Sciences for over 25 years, serving on its Theater Standards Committee, and have been published in Mix Magazine, Recording Magazine, the Cinema Audio Society Quarterly, and the Motion Picture Editors Guild Magazine.

In 2009, I officially hung out my shingle as MediaRooms Technology LLC.

Essential Elements For Designing Acoustically High Performance Spaces

brucedblack@mail.com

Over the course of all my reading, and sixteen years of practice as an acoustical designer, I have found there are nine factors that are needed to ensure success – the essential elements for designing high performance studios. Some will seem to be common sense and obvious, while others may seem like downright heresy. But omitting any one of them can sabotage your efforts and lead to a failed project.

So let's take a look at these elements…

Element 1: Well Defined Goals

brucedblack@gmail.com

In any project, a successful completion requires comprehensive, well defined goals.

In studio design, we all want our projects to be “good rooms”, so it’s important to detail what the definition of a “good room” is. This gives a sharp focus and direction to the design efforts and determines our specific objectives and targets. It becomes a fixed reference point to guide the design and construction processes, from initiation, to completion, to running the inaugural sessions

Simply put, if you don’t know where you’re going, how will you know when you’ve arrived?

To my way of thinking, the ideal music, mix and playback rooms, require a neutral room sound, and provide an accurate representation of what’s being recorded or played back. This is particularly important in highly collaborative work, like post production sound editorial, where a track can get played in many, many rooms.

The one thing an editor doesn’t want is a phone call from the mix stage, with an irate mixer demanding, “What the hell did you send me??” That’s how some people talk in Hollywood.

And for the ideal live recording environment, a good recording comes from a room that is free from harsh reflections, doesn’t add colorations, and provides a pleasing aural environment or sense of space.

Within these parameters, the studio’s characteristics may need to be adjusted, to accommodate the studio’s intended use, such as Foley recording, and to accommodate variations within the room’s specialty. ADR studios in particular need to be able to replicate spaces from tiny closets to the great outdoors.

These adjustments can be accommodated with variable acoustics, specialized gobos, and other such things, and it’s important to know up front if you will be needing any components like these.

For example, a specialized custom gobo designed for Woodshed Recording in Malibu.

www.WoodShedRecording.com

brucedblack@gmail.com

As an example of well defined goals, the owner of Woodshed Recording in Malibu, Richard Gibbs, asked me to design a specialized gobo for him.

Normally, this would be a straightforward device; one would just build a simple wood frame, stuff it with an absorbent, cover it with fabric, and maybe add some wheels, and call it good. You might even include a window if you're feeling ambitious.

But as you can see, Woodshed Recording is visually very stunning, with close attention paid to the details, to appeal to their demanding, top-tier clientele. A plain vanilla gobo wouldn't do.

So Richard gave me an extensive list of requirements, as he had many more considerations than a simple, bang-it-out gobo would satisfy.

- As you can see, Woodshed is a unique, variable, open concept studio, so the gobos need to provide especially good isolation to acoustically divide the room.
- The design and coloring must match that of the studio, to fit in well with the existing carefully manicured look.
- They must create a very comfortable visual environment for artists
- Multiple gobos must nest tightly together to enhance the isolation of a solo artist.
- The design must be very flexible so a few gobos cover a wide variety of requirements.
- They must be easily moved by one assistant.
- And be able to clear door openings without having to be tipped over or disassembled.
- They must be easily removed and stored, including negotiating stairs.
- And they must accommodate artists who don't like working in the presence of fiberglass.

That's a lot of pretty specific stuff, eh? It may seem very challenging, but I like a client who has concise ideas about what they want. It actually makes my job easier by not having to second-guess any details.

So it's important to remember that vague goals, like "I want it to sound good" don't give you any sense of direction.

It reminds me of when a food truck once asked me what kind of sandwich I wanted. I said, "Surprise me." They certainly did, but it was not the awesome culinary adventure I had hoped for. The lesson for me was, "Be detailed and specific."

For example, a specialized custom gobo designed for Woodshed Recording in Malibu.

brucedblack@gmail.com

So once Richard and I were clear about what we wanted to accomplish, we could select and shape all the elements that would fulfill these goals.

So we were able to incorporate a great number of capabilities into an otherwise simple device. Specifically -

For example, a specialized custom gobo designed for Woodshed Recording in Malibu.

brucedblack@gmail.com

- An internal layer of ½ inch plywood to provide a barrier for good isolation **through** the gobo.
- They're also divided into upper and lower pieces. Each piece can be used independently or together, as needed. This also allows for disassembly for easy transport and storage.

- Even those odd-looking feet serve multiple purposes. They of course conceal the casters, which provide the easy positioning. They also have a very close clearance to the floor to brush cables aside so as to not run over them. The long left foot keeps the gobo vertically stable, while the short right foot allows multiple gobos to nest in a very tight semi circle, which you will see in a moment.

- Meanwhile, each gobo is 79 inches tall, allowing it to be rolled through standard 80 inch doorways, upright and fully assembled.

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brucedblack@gmail.com

- The upper portion has sound absorption on one side, and high performance diffusion on the other. If you want a tight, intimate sound, you use the absorptive side. If you want a more open, airy sound, you use the diffusive side.

- The lower portion is absorptive on one side, and reflective on the other. It also has an integral Helmholtz resonator, tuned to 95 Hz., with the port concealed between the two feet. The resonator provides an organic low frequency filter in the hopes of avoiding having to use the electronic high pass filters on the microphone and the mic preamp.

- You can also unlatch the top and rotate it to use what ever combination of surfaces you need, and have varying combinations within a cluster of multiple gobos.

For example, a specialized custom gobo designed for Woodshed Recording in Malibu.

brucedblack@gmail.com

- Here’s the bottom, showing the port for the resonator.

- The casters are visible in the boxy feet on the bottom, which allow the gobo to be easily moved around by one person.

- The mahogany wood has an oiled redwood finish that matches the studio’s existing woodwork, and the fabric color matches the fabric and paint already used in the studio.

- And, in order to put to rest any artist’s concerns about fiberglass, UltraTouch recycled denim insulation was the sound absorbent used.

For example, a specialized custom gobo designed for Woodshed Recording in Malibu.

brucedblack@gmail.com

And here you can see how nicely they nest together, so they form a tight half circle surrounding the artist, providing both good isolation around the **edges** of the gobo, and privacy for the artist.

You can also see a bit of the dual pane window in the left-most gobo. We fashioned this out of two sheets of Plexiglas, one on each side to maintain isolation through the window, and both are curved to prevent hard reflections off the panes.

Wow. All this for a mere gobo? But this gobo has some really big shoes to fill, to be able to nimbly handle all the tasks required of it.

So clear, detailed, well defined goals rewarded us with good results, and made this complex gobo simple to design. And while going from a gobo to a complete studio may seem to be quite a leap, the importance of detailed planning remains the same. The only difference is the scale. Comprehensive, well defined goals give us a complete, unambiguous sense of direction and clarify the path forward for creating a high performance acoustical space efficiently.

Element 2: Use Rectangular Rooms

brucedblack@gmail.com

Boy, this one flies in the face of conventional wisdom, doesn't it?

There have been plenty of discussions that insist walls *must not* be parallel.

But so far I've never found any discussion that gives good reasons *why*, and what specific benefits it offers.

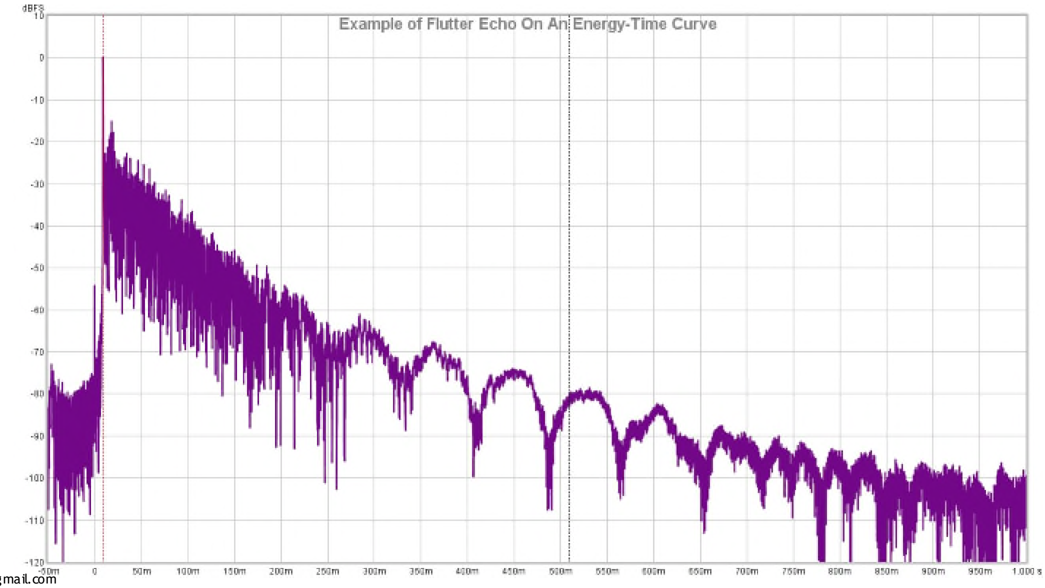
This is kind of like when common wisdom said, "the Earth is flat, all you have to do is look", and some heretic said, "Wait a minute…"

But when challenging something that many people take as gospel truth, one had better be well prepared to satisfactorily explain this seeming blasphemy.

So here's what I suspect leads people to consider splayed walls a must –

Flutter echoes and room resonances.

Flutter Echo, Graphed



brucedblack@gmail.com

So first, let’s look at flutter echoes.

This is an Energy-Time graph, displaying level, or energy, on the vertical axis, and time on the horizontal axis.

It shows the reflections in a room.

This one represents 1 second of time, and the highest point on the left side is the arrival of the direct sound at the measurement mic.

Initially, the signal looks pretty random, which is what we want for a “good sound”.

But at around 250 ms., the reflections start clumping together, developing into some unmistakable humps.

These well defined humps are flutter echo. You can see that they repeat at a specific interval, which correlates to the distance between the two reflecting surfaces that create them.

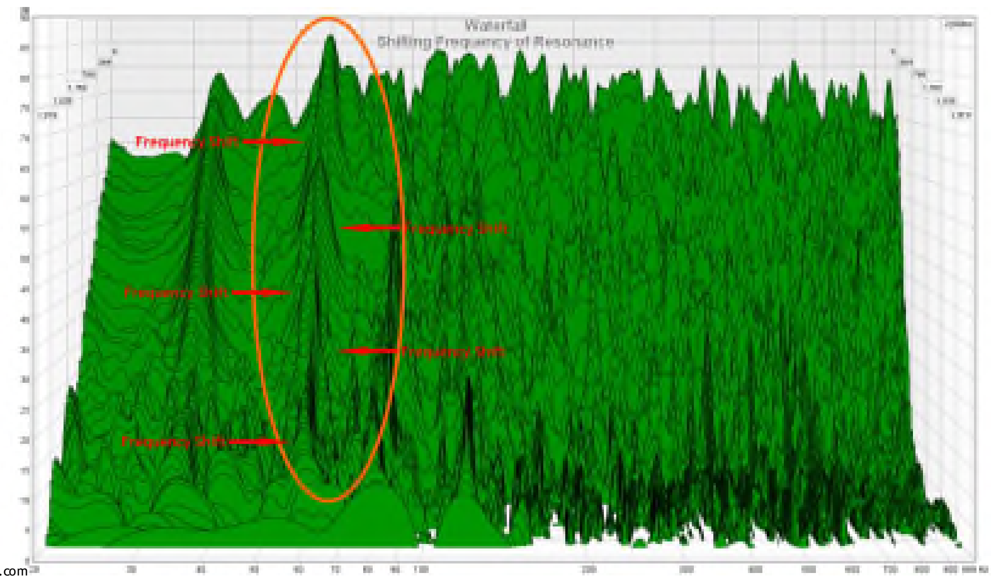
This gives them their distinctive sound.

And if you multiply the speed of sound by the time interval of the humps, you will find the dimension that has the flutter echo.

This makes identifying the offending room dimension easy, giving you a good idea where the anti-flutter treatments should be placed.

Also, non-parallel walls shift the duration of each “hump” by changing its specific dimension. This may make the flutter echo seem to disappear, fair enough. But the hard reflections remain.

Example of A Frequency-Shifting Resonance



brucedblack@gmail.com

Meanwhile, I've heard some say that non-parallel walls get rid of room resonances, also known as modes, standing waves, eigenmodes, and so on.

This is not the case; every room will **always** have resonances. We'll discuss this more in-depth shortly.

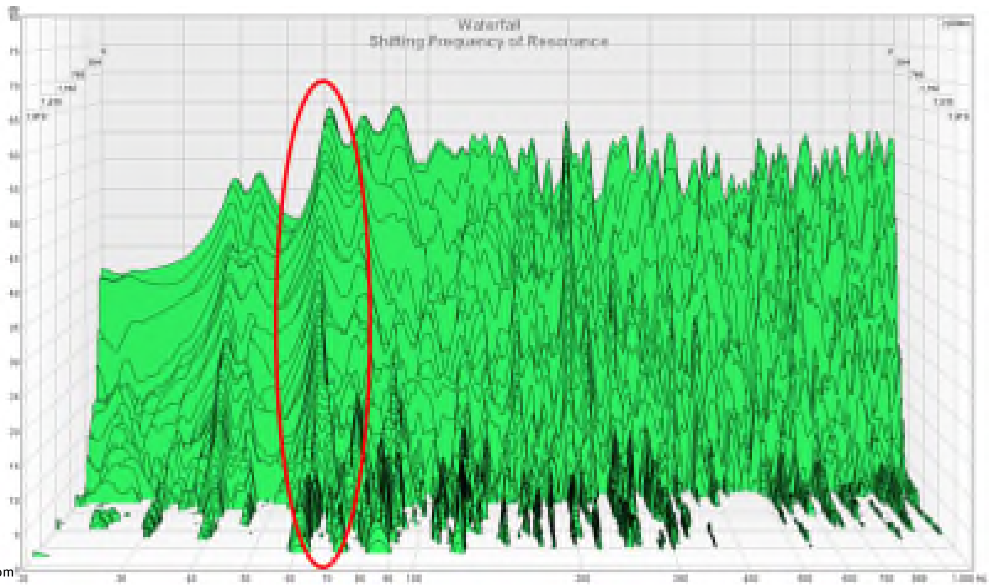
In a room with non-parallel walls, this splaying only shifts their frequency and distorts them to where it's difficult or impossible to control them.

In this waterfall graph, those ridges you see are the room's resonances. You can see the 60 Hz. resonance shifts frequency, snaking back and forth.

This room was not **intentionally** built with non parallel walls, so the variation will be small.

But if this was a room with intentional splaying, the slithering of this resonance would be much more pronounced.

Example of A Frequency-Shifting Resonance



brucedblack@gmail.com

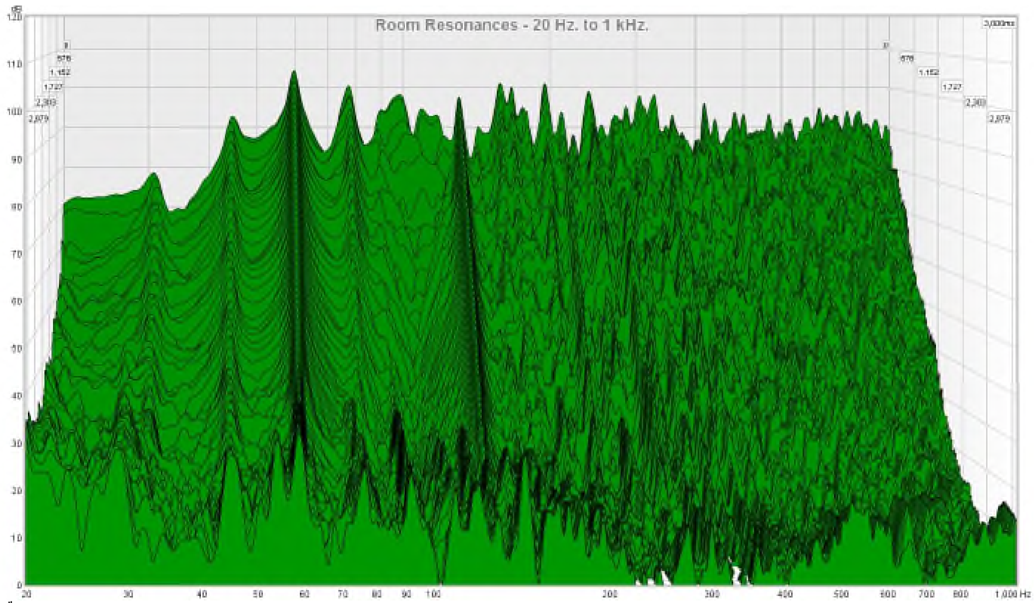
And here is another room with a similar situation.

You can see how the 70 Hz. resonance bows left and then right.

Variations in how walls are made non-parallel result in different patterns of shifting, but any room with fluctuating resonances indicates there are problems, perhaps even poor construction.

So a room like this will likely have other problems as well.

Example of Rock Solid Resonance



brucedblack@gmail.com

In contrast, this room has resonances that are straight as an arrow! These were very easy to treat.

There's no question that the treatment for a resonant frequency at 0 milliseconds, the direct sound, will continue working well as time progresses, to roughly 2000 milliseconds of overall decay in this instance, because the frequency is not shifting.

Notice also the high Q, or the sharpness, of the resonances. This is the result of drywall or wallboard panels that were made very stiff by using closely spaced drywall screws and generous construction adhesive on the framework and between the layers. Careful attention was also paid to the squareness of the room by maintaining tight tolerances with the dimensions. We'll also discuss **THIS** a little later. This means there is less energy in the resonances, which reduces their audible effects on the listening experience. While the resonances remain, their influence on the room's sound is diminished. Perhaps almost as good as "getting rid of them", and without the problems.

Another View Of Splayed Walls

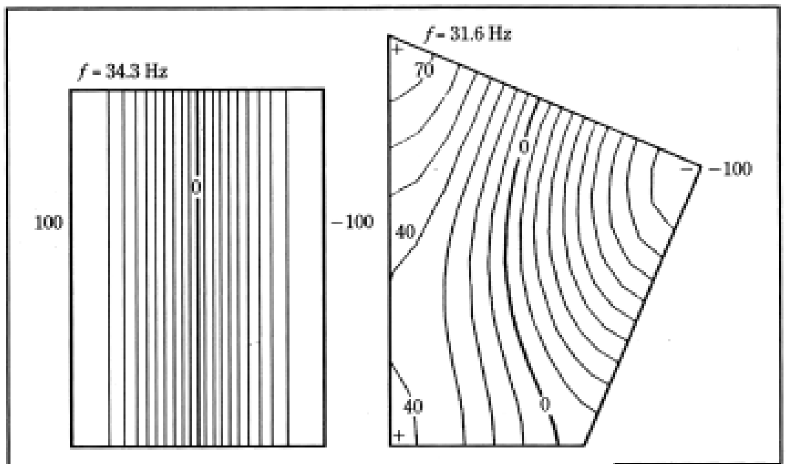


FIGURE 13-10

Comparison of the modal pattern for a 5 x 7 meter two-dimensional room and a non-rectangular room of the same area. This sound field of the 1,0 mode is distorted in the nonrectangular room and the frequency of the standing wave is shifted slightly.[8]

brucedblack@gmail.com

Here is another way to illustrate room resonances.

These are overhead views of a room's footprint, known as a plan view in architectural terms.

The dark line is the resonant peak, and the lighter lines represent diminishing energy as you move away from the peak.

Here we see how the peaks and decays of the width's first resonance fall in rectangular and irregular shaped rooms of the same volume.

On the left graph, you can see how orderly and predictable the resonance is.

This means, as you move around the room, your perception of the low frequency response may change, but it will remain uniform, predictable and unconfused. For those who missed my low frequency talk, the low frequency range is where we get the bulk of our perception of audio quality.

With the graph on the right, you can see how even small changes in a listener's position can alter what they hear, in inconsistent and unexpected ways.

This also creates listening fatigue earlier, and may be part of the reason why some rooms are mysteriously uncomfortable to work in.

While this shape is a bit over the top, it illustrates the problems that can arise even with less exaggerated rooms.

These graphics are from F. Alton Everest's Master Handbook of Acoustics, Fourth Edition.

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Another View Of Splayed Walls

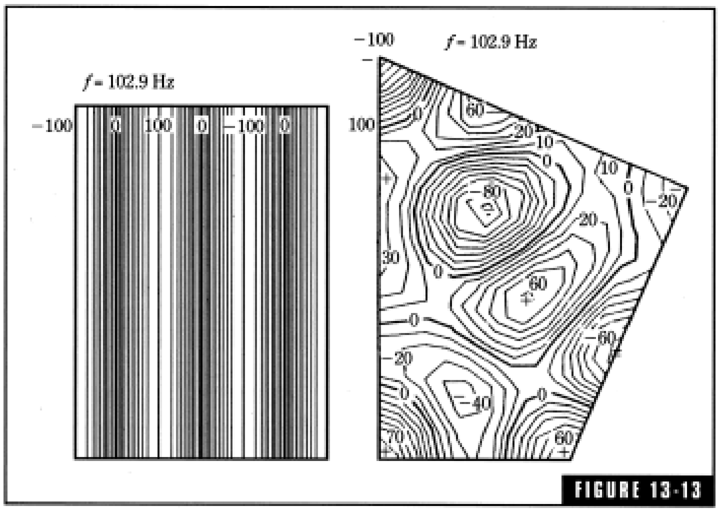


FIGURE 13-13

The 3,0 mode of the 5 x 7 meter two-dimensional room of Figs. 13-10 and 13-11, and 13-12 and resulting distortion of the modal pattern when changed to a nonrectangular room of the same area.[8]

brucedblack@gmail.com

Now we up the stakes.
In this view, we see the **third** resonance of the width.
On the left, things remain uniform and orderly, while on the right things become more and more chaotic.

Another View Of Splayed Walls

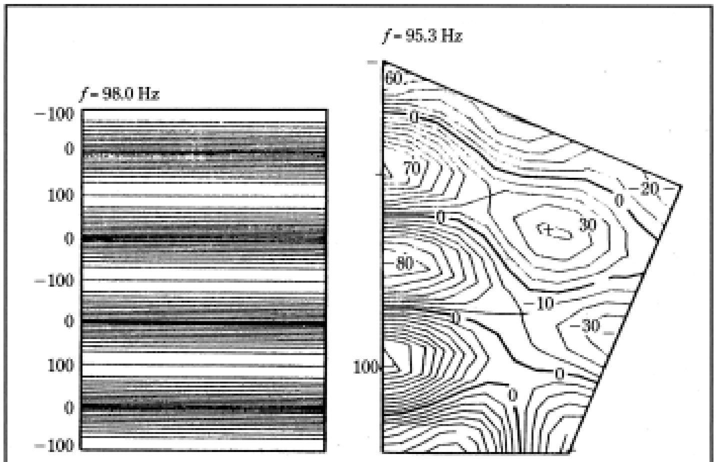


FIGURE 13-12

The 0,4 mode of the 5 x 7 meter two-dimensional room of Figs. 13-10 and 13-11. The high distortion in the rectangular room is accompanied by a shift in standing wave frequency.[8]

brucedblack@gmail.com

Here we see how the **fourth** resonance of the **length** manifests itself.
On the right, it looks very confused, and that's how it sounds.

So I'm beginning to pick up a pattern here.

While things remain orderly in the rectangular room, you can see that the irregular room's modal response gets increasingly complicated and confused.
And in fact, in the caption, F. Alton Everest describes this as "high distortion accompanied by a shift in standing wave frequency". Just like the bowing we saw earlier in the waterfall graphs.

Another View Of Splayed Walls

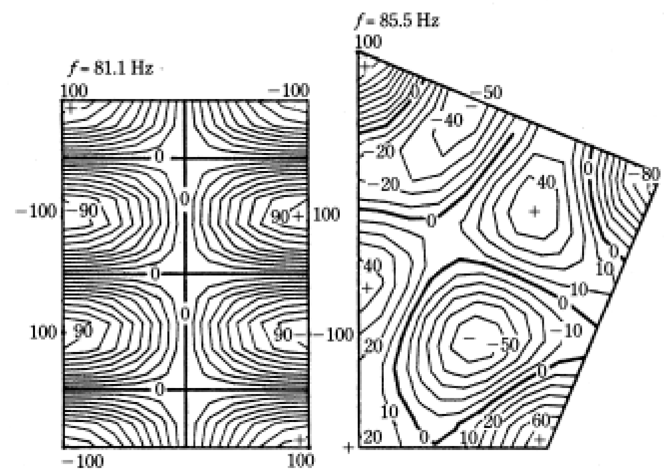


FIGURE 13-11

The 1,3 mode for the 5 x 7 meter room of Fig. 13-10 compared to a nonrectangular room of the same area. The sound field is distorted and the frequency is shifted.[8]

brucedblack@gmail.com

Now let's combine two resonances - the first width and the third length resonances.

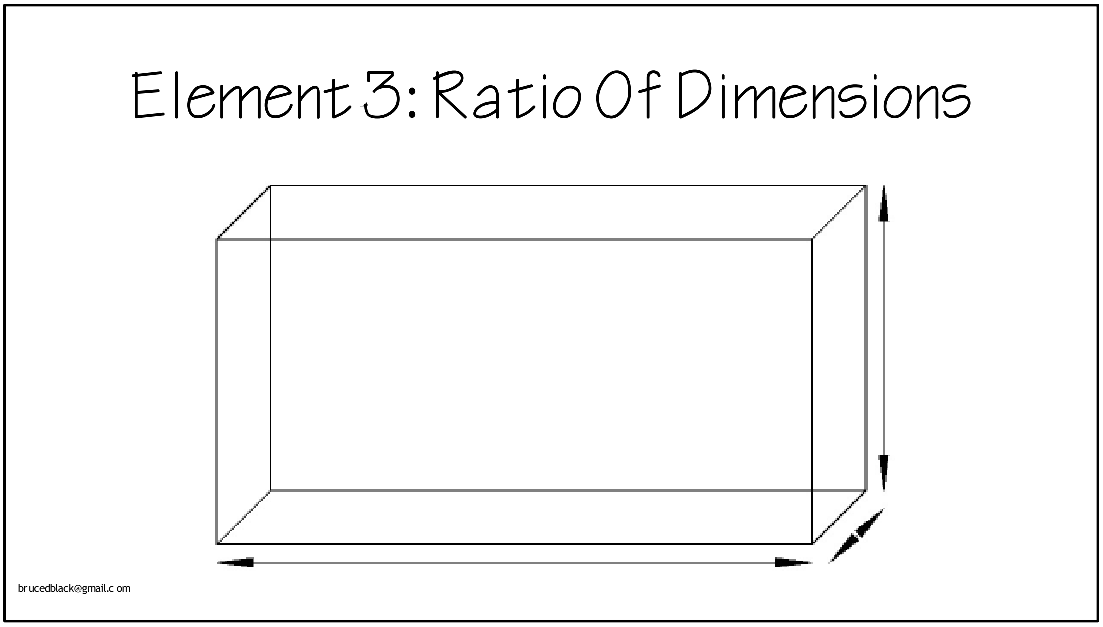
As the graphs progress to more complexity, the resonances in the rectangular room continue to fall in an orderly fashion, while the irregular room continues to be, well, quite irregular.
If you were to overlay **all** the graphs of the rectangular room you would see an overall pattern that was very complex, but very orderly.

And as you moved around while listening, the low frequency would have orderly changes in timbre, and the sonic changes would be mirrored, side to side and front to back. This gives you the confidence that you're hearing an accurate representation of the recorded material.

In contrast, if you overlaid all the graphs from the irregular room, it would be very disorderly, uneven and confused.
Moving left or right, or forward and back, the sound would change in asymmetrical, and unexpected ways. This leaves you never knowing if the anomaly you're hearing is in the recording or an artifact of the room's acoustical signature.

So both rectangular and irregular rooms bring their unique characteristics to the acoustical environment.
One provides you a consistent sonic field that instills confidence in what you're hearing on the recording.
The other changes the sound inconsistently, leaving you unsure of what is on the track.
But the problems that parallel walls bring are easily fixable, likely with the very treatments you'd be installing anyway.
Non-parallel walls damage the acoustic environment in ways that are irreparable. There is no way to fix the problems caused by an irregular room. You might get a little relief with band aid fixes, but there are **no** acoustical treatments that will **fix** these problems - it will **never** be as good as a rectangular room with the flutter echoes treated.

As complex as all these graphs may look, they are still simpler than when you've excited all the resonances with truly complex sound like we experience in everyday life.



Perhaps the **<u>most important process</u>** in designing a room is to adjust the room's dimensions and ratios until you have an even distribution of <u>all</u> the room's resonances in the frequency domain.

This has the greatest influence on a room's sound quality. Get this right, and you almost have to **<u>work</u>** to make it sound ***bad***.

The best results come from an iterative process, where you keep plugging in numbers and looking at the results.

You **<u>can</u>** use shortcuts like the Golden Mean, Fibonacci Numbers, and Bolt area ratios; they will bring you performance that's much better than choosing random dimensions or using the room's existing dimensions.

But there is no substitute for working through the calculations. This has consistently provided the best sounding rooms.

This optimal performance always comes from calculating each set of dimensions one at a time until you get the most even distribution.

There will, of course, be constraints that you must adhere to, like a wall that can't be changed, or dimensions that would be absurd. But there are also times when adjusting even one dimension will give you a hefty leap in performance.

Adjusting room dimensions in this fashion is one step where you absolutely want to put in the time and not take any shortcuts.

It makes that big a difference.

Sample Room Resonance Calculation

brucedblack@gmail.com

This is the first page of a spreadsheet I created for calculating room resonances.
The dimensions of this sample room were chosen to demonstrate how the spreadsheet works, and include a cardinal sin of room design – making two dimensions exact multiples.

The first section of the spreadsheet calculates the axial, or primary, resonant frequencies. These exert the greatest influence on a room’s sound, and this spreadsheet calculates the first 60, up to at least 300 Hertz. Those ridges we saw earlier in the waterfall plots are axial resonances.

Beyond 300 Hertz, the quantity of resonances, plus the addition of tangential or secondary, and oblique or tertiary resonances significantly dilutes the effect any single resonance can have on the room’s sound.

This spreadsheet also calculates the differences between the low frequency axial resonances, and color codes any that may be problematic, using standard cautionary colors. This allows me to easily scan their distribution, scrutinized their relationships, and adjust the room’s dimensions to correct the issues.

So, in the right column -
The numbers in white show the spacing of resonances that are good to go.
The numbers in yellow caution you to resonances that are getting too close to each other.
Orange numbers flag too much distance between adjacent resonances.
And finally the red numbers alert you to resonances that are piling up on each other.

You can see the cardinal sin of matching dimensions triggers the red color.

Sample
Room Resonance
Calculation

Mode Number	p,q,r	frequenc	axial	tangentia	oblique	difference
1	1,0,0	31.35	A			7.58
2	0,1,0	38.97	A			11.07
3	1,1,0	50.04		T		12.74
4	0,0,1	62.78	A			[illegible]
5	2,0,0	62.78	A			7.45
6	1,0,1	70.19		T		3.70
7	0,1,1	73.89		T		[illegible]
8	2,1,0	73.89		T		4.04
9	0,2,0	77.93	A			2.35
10	1,1,1	80.28			O	3.74
11	1,2,0	84.01		T		4.77
12	2,0,1	88.78		T		5.33
13	3,0,0	94.11	A			2.79
14	2,1,1	96.90			O	3.12
15	0,2,1	100.07		T		[illegible]
16	2,2,0	100.07		T		1.84
17	3,1,0	101.91		T		2.97
18	1,2,1	104.88			O	8.30
19	3,0,1	113.17		T		3.72
20	0,3,0	116.90	A			1.24
21	2,2,1	118.13			O	1.90
22	3,1,1	119.03			O	2.54
23	3,2,0	122.23		T		3.32
24	0,0,2	125.56	A			[illegible]
25	4,0,0	125.56	A			5.91
26	0,1,2	131.46		T		1.22
27	0,3,1	132.69		T		[illegible]
28	2,3,0	132.89		T		2.47
29	1,1,2	135.16			O	1.15
30	1,3,1	136.35			O	1.06
31	3,2,1	137.41			O	2.95
32	2,0,2	140.39		T		5.37
33	2,1,2	145.88			O	[illegible]
34	4,1,1	145.60			O	1.11
35	2,3,1	146.75			O	[illegible]
36	0,2,2	147.77		T		2.33
37	3,3,0	150.11		T		[illegible]
38	1,2,2	151.07			O	4.75
39	0,4,0	155.90	A			1.00
40	3,0,2	156.94		T		[illegible]

brucedblack@gmail.com

Scrolling down to the second section, we see the fields that show the tangential and oblique resonances, in addition to the axial ones.

These numbers allow us to see what's happening around a problem resonance, and determine if the room's dimensions need further attention, or if the lesser resonances surrounding it sufficiently dilute the problem.

But with the addition of tangential and oblique resonances in this table, it's inevitable that there will be more and more closely spaced resonances, triggering colors. So you have to interpret these with a more forgiving eye.

In the end, you examine all the data, juggle the dimensions for improvements, and make your final determination, settling on a set of dimensions that also fit the space available, the architectural requirements of the facility, the restraints of budget and construction, and building code requirements.

There are always compromises that must be made, but this provides a process that will maximize a room's sonic quality within the constraints of the project.

Once this is completed, you're on the way to creating a room that will serve you and your clients very well acoustically.

Element 4: Isolation

brucedblack@gmail.com

This is all about keeping outside sound out, and inside sound in. If you're in a noisy neighborhood, have multiple studios that work simultaneously, or have a workspace in a multi-tenant building, this is particularly important.

A good recording is, among other things, one that is not contaminated with extraneous sound finding its way on to the track, and a good neighbor is one who doesn't annoy those living or working nearby with their loud projects or late night work hours.

Excellent isolation provides you with clean recordings, and allows you to work whenever you want, regardless of how loud your project may be or how late you're working.

One project of mine posed an isolation challenge that was particularly demanding. The client had chosen a building at a major Hollywood intersection; noisy, with much heavy traffic on a major arterial street. This presented a near constant stream of buses, tractor-trailers, trash trucks, and the like.

My recommendation to find a better location without so much noise, was met with a shrug. This would be the place. Period. The client had already signed the lease by the time I was brought in.

Their recording specialty required a particularly quiet studio, so there was much very careful work to be done. It was not easy or cheap.

We made it work well, but it underscores the basic fact that the easiest path to a quiet recording environment starts with a quiet neighborhood. And a location that is convenient for clients but noisy may also be a budget buster to build.

This contrasts with a Foley studio that was built in a sparsely inhabited area. It was easy to keep the outside sound out, as there wasn't much that could find its way in. This was much easier to deal with in the design.

Isolation

brucedblack@gmail.com

Sound isolation is also about minimizing leakage between spaces, and deals with room surface layers, floating floors, room penetrations, and the like.

Since an amazing amount of sound can travel through a surprisingly small opening, the first line of defense in creating good isolation is to make it airtight. In order to minimize sound leakage, all of the room's surfaces, as well as the doors and windows, need to be sealed up tight.

The **biggest** offender for leakage is doors. Their bottoms require special attention, using hardware like drop seals, gasketed thresholds, and so on. Likewise, the door's edges need to be sealed, yet with all of this, the door still needs to remain easy to open and close. It can be challenging. Windows, the same.

And when building a room, it's best to caulk **all** the joints of **all** the drywall panels, before finishing them. Drywall compound is just not a good sealant.

Gluing layers of drywall together with construction adhesive also enhances isolation by making the wall denser and more rigid.

And don't overlook the penetrations for utilities, like electrical boxes and plumbing. This means anywhere a pipe, conduit, or duct enters a room, it must be tightly sealed. And electrical boxes, like switches and outlets, need to be sealed. In addition to caulking around the box, you can also install thermal gaskets under the covers.

Another source of leakage can masquerade as an airtight wall. We think cement block walls are airtight, because they're heavy and thick. But some cement used in making blocks is deliberately quite porous to make them lighter, so sound is able to travel through it.

For this, there's a simple solution - paint all of the block wall with a water proofing paint.
If it will block water, it will block air and sound.

The fundamental thing to remember is that if air can move, sound will travel.

Isolation

brucedblack@gmail.com

In the meantime, we all know that sound travels through air, but it's very easy to overlook sound's ability to travel through solids.

But sound traveling through solids is an important factor in room design; it's a major path for both incoming and outgoing sound migration.

As mentioned before, the speed of sound in air is around 1,130 feet per second.
In solids, it's quicker – wood and steel can transmit sound at up to 5000 feet per second.

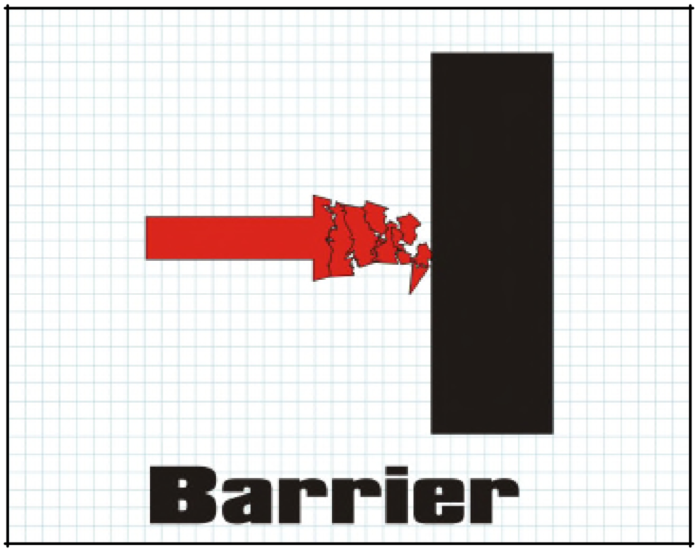
So for example, when a speaker has direct, solid contact with the room's physical shell, its cabinet vibrations enter the room's structure and travel through the building faster and more efficiently than through air.

Eventually this energy finds an unrestrained panel, like drywall between framing members, perhaps in another room, and excites that panel into motion. Generating sound like a speaker cone, albeit a poor quality one. And there you have your loss of isolation.

This may be the biggest contributor to your inside sound getting out and disturbing people in adjacent rooms or your neighbors.

This is also true of motorized equipment like air conditioning compressors or fans bolted to the building structure.

Isolation

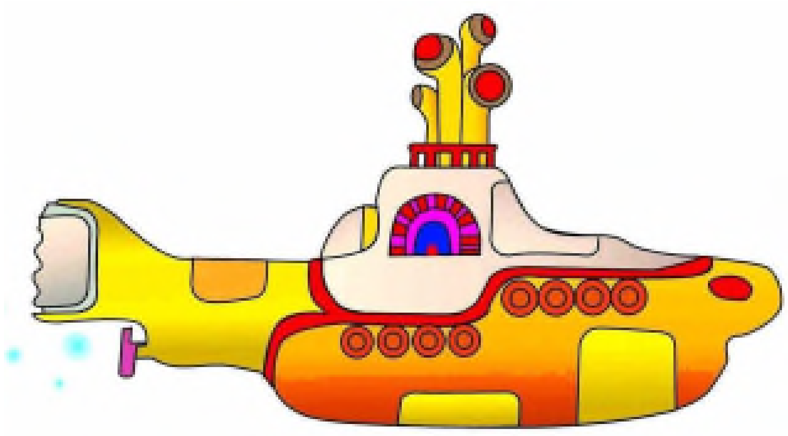


brucedblack@gmail.com

Another aspect of isolation involves drywall.
It’s a good material to create a barrier layer to airborne sound.
It’s dense, heavy and inert – everything you want in a barrier.

You can also use plywood as one of the layers, as it also has a high density, like drywall.
But it also gives the benefit of being a layer you can securely screw things to.

Isolation



brucedblack@gmail.com

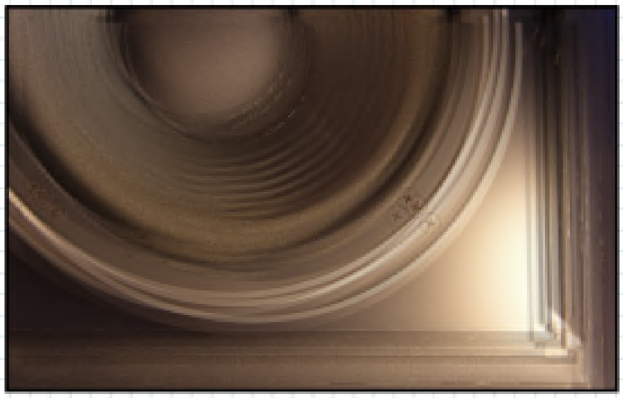
And density **changes** can be employed.

In World War Two, submarines were able to evade pursuers by hiding below a temperature gradient, with it's change in water density. This reflected sonar pulses back toward the surface, and the sub's sound back down.
A variation of a few degrees over a few feet in depth could make the difference between life and death.

And this goes back to layers of drywall and plywood.
They're both dense, but they're around 10% different.
Used together to take advantage of the variations, they provide enhanced isolation.

All this shows that we can further improve our wall isolation with carefully employed changes in density.

Vibration Isolation



brucedblack@gmail.com

And then there's your speakers…
In containing your room's sound, your speakers pose another problem, requiring another kind of isolation.

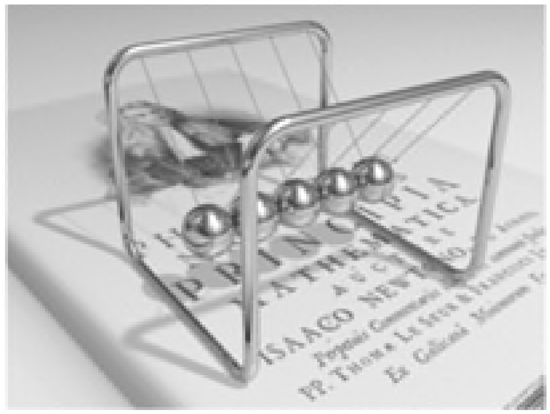
As I mentioned earlier, if your speakers have a solid connection to the building's structure, the low frequencies can transfer through it, and migrate into other rooms. Motors and compressors too,

There, they excite unrestrained panels into motion, reradiating that sound into that room.

This is a particular problem with subwoofers, with their high energy low frequency sound, the culprit when you hear the thump from speakers in another room.

Here's how that works…

Vibration Isolation



brucedblack@gmail.com

This is called a Newton's Cradle, demonstrating The Laws of Conservation of Momentum and Energy.

Imagine the speaker is on one end, releasing its energy like the first ball.

The middle three balls represent the building structure, and the end ball represents an unrestrained wall panel.

Note that the middle balls don't need to move to transfer the energy.

The energy from the speaker is released, like the first ball.

The energy transfers down the building's structure, like the center balls.

Then, like the end ball, the energy excites the unrestrained panel into motion, reradiating that sound.

But the solution is simple –
You use vibration isolation to decouple the speaker from the structure.

Vibration Isolation

brucedblack@gmail.com

The array of isolators that are available range from simple to elegant, low priced to expensive, and moderately effective to **really** effective.

Products like this one are supports that provide what I call a high impedance contact. This resists vibration energy migrating across it due to the very small pin-point area of contact.

Vibration Isolation

brucedblack@gmail.com

Some people use heavy blocks under their speakers, based on the idea that the heavier an object is, the harder it is to set it into motion.

That's true, but with Newton's Cradle, we see that an object doesn't have to move to transfer the energy. So while this may sound like it should be a good idea, it doesn't really work.

Vibration Isolation

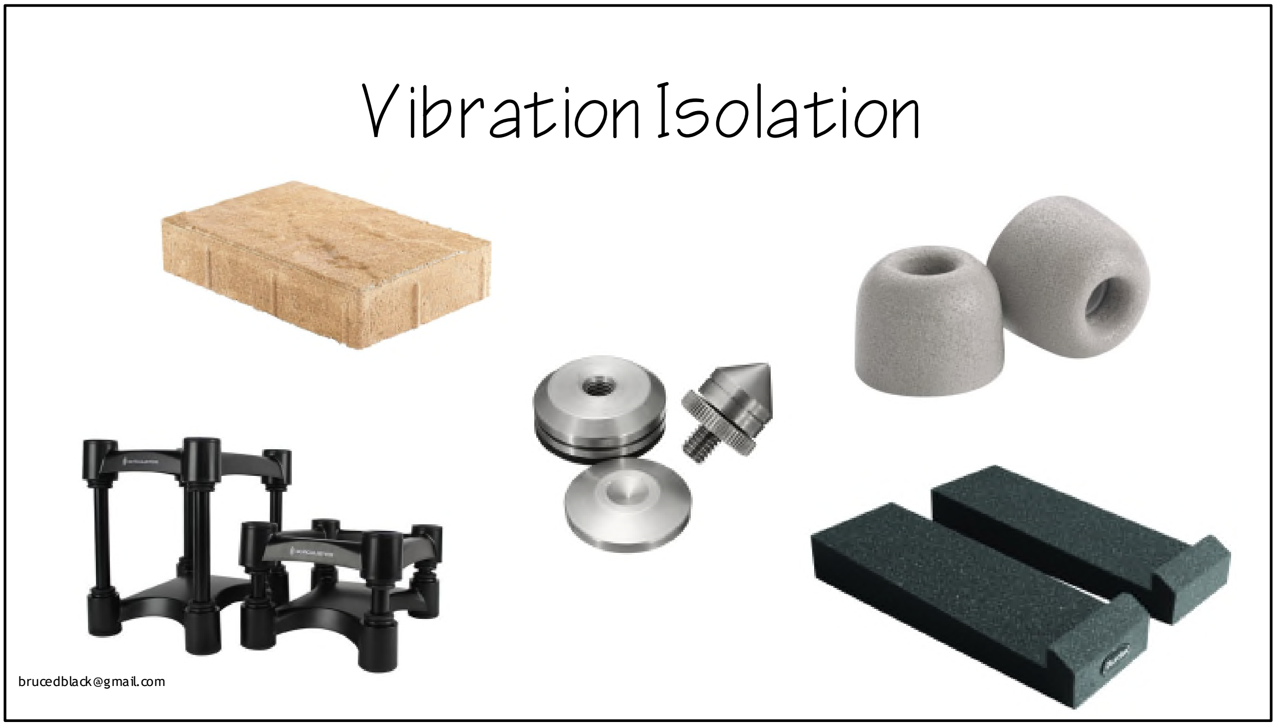
brucedblack@gmail.com

And marvelous frames that both isolate and raise your speakers to a good listening position, while tilting the speaker toward the listening position…

Vibration Isolation

brucedblack@gmail.com

…resilient foam pads that dissipate the energy also while tilting the speaker toward you…



And special resilient feet for your speaker.

There are many devices available.
Some are rather clever and display a thorough understanding of all the facets of the problem.

Myself, I prefer a solution that is effective, unobtrusive, and inexpensive.
And that would be a marvelous material called Sorbothane.

Vibration Isolation

brucedblack@gmail.com

These are Sorbothane hemispheres.
They work extremely well, having been developed for the space program.
They're small, and nearly disappear under a speaker.
And they're quite inexpensive.

To work properly, the speakers have to float freely on them.

But with whatever vibration isolation you choose, start with your subwoofers – they're your "worst offenders".

There are also Sorbothane products that can be used under machinery, like air conditioning compressors and motors to block their structure-borne rumble and noise.

(Halfway Point)

Vibration Isolation

brucedblack@gmail.com

Here is a speaker mounted on the Sorbothane hemispheres.

It's important that the isolators are the only thing touching the speaker, to prevent cabinet vibrations from flanking them and getting into the rooms structure.

(Halfway Point)

Element 5: Sound Absorption

brucedblack@gmail.com

Everyone knows that absorption removes acoustical energy from the air, making this the most common go-to acoustic treatment.

Studio designers use this to control a wide range of room characteristics, like the decay or reverb time, reflections, and similar things.

Unfortunately, this popularity results in overuse, leading to dead, **INACCURATE** rooms. It must be used judiciously and properly, so be careful how much you use.

But first, let's look at what types of absorptive insulation are available.

Element 5: Sound Absorption

brucedblack@gmail.com

Perhaps the best known is fiberglass rolls or batts, like you get at a home center.
When handling this, you want to wear protective gloves and a face mask – this stuff is **<u>very</u>** irritating.

But it works well, is inexpensive, and readily available.

Element 5: Sound Absorption

brucedblack@gmail.com

This next one is the popular Owens-Corning 703.

This is also fiberglass, except it's a rigid board, so it will stand up and hold it's shape in applications that require that.

I always use 2 inch, due to where its high frequency absorption rolls off.

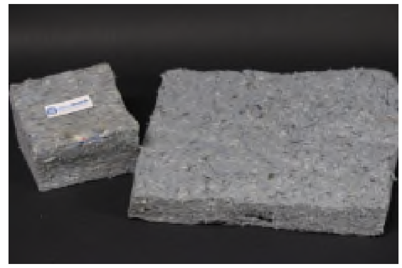
For wall panels, you can cover it with acoustically transparent fabric, which keeps it from shedding fiberglass particles if you brush up against it, while not impacting its absorptive performance.

These covered panels can also be suspended over the listening position as clouds.

But you still have to wear protective gear when working with this.

For those who'd rather not be in the same BUILDING as fiberglass, there are other types that you can use.

Element 5: Sound Absorption



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This material is UltraTouch, made from recycled denim, like we used in the gobo.

<u>This</u> one is completely non-irritating – you can breathe through it..

The one drawback, though, is that it won’t stand up on its own.

It needs to be supported or held in place.

But there’s one more choice that does fit that bill.

This is PET wall panel material. It’s also know as PETE, or polyethylene terephthalate for science buffs like me.
Like the UltraTouch, this is non-irritating. It’s rigid enough to stand up on its own, so you can make effective and attractive absorptive panels by wrapping it with acoustically transparent fabric.

It’s made from recycled beverage bottles, so it’s green and sustainable.

It was originally designed for padding under fabric walls, but some testing by Riverbank Labs showed it also has acoustical performance similar to 703.

It is not easy to find, however it is available from a number of distributors and manufacturers if you search for it.

These are all what we call resistive absorbers – they affect the **particle motion** of sound. There are also **resonant absorbers**, which work on sound **pressure**.

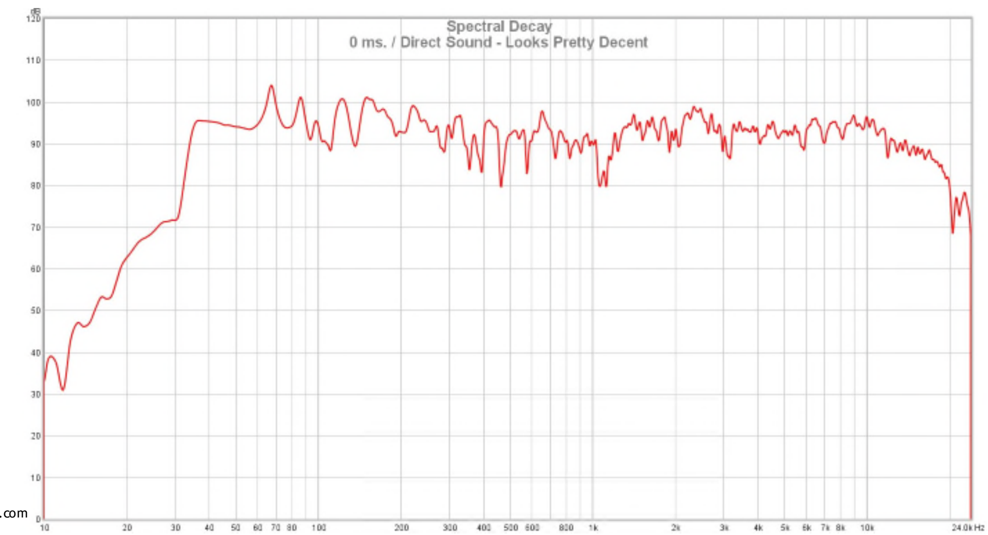
So as the popular, best known, go-to treatment, it’s easy to fall into the trap of trying to fix **all** your acoustical issues with resistive absorption.

In a situation where something doesn’t sound right, but the cause evades us, we frequently just throw more absorption at it, and hope for the best.

But you can have too much of an good thing.

So for the best acoustical performance, it’s important to first identify what the problem is, and then fix that issue appropriately.

Room Absorption



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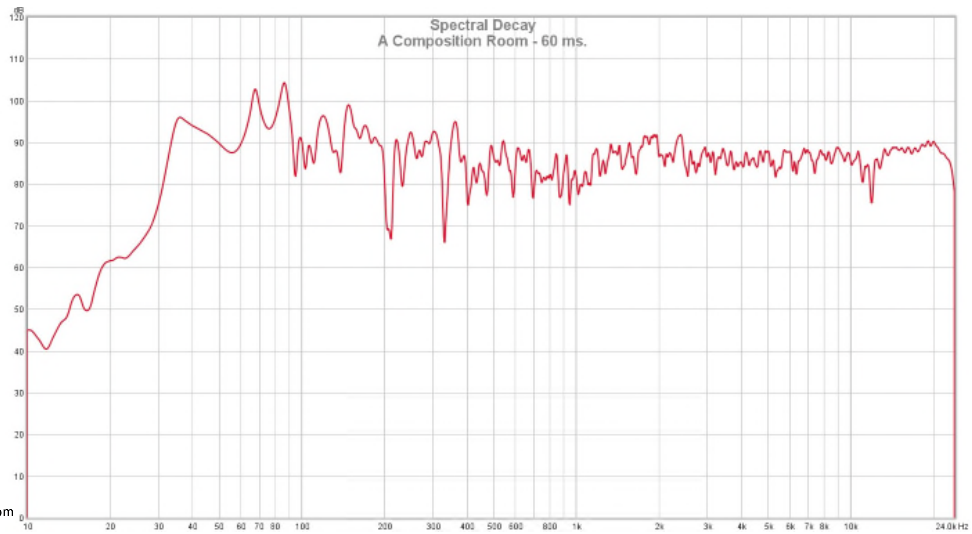
So what's wrong with using an excessive amount of absorption? Check this out.

This is a frequency response graph of a composer's room, showing the initial sound, also known as the direct sound.

It's pretty much what a real time analyzer would show you.

This would seem to indicate the room looks good and usable.

Room Absorption



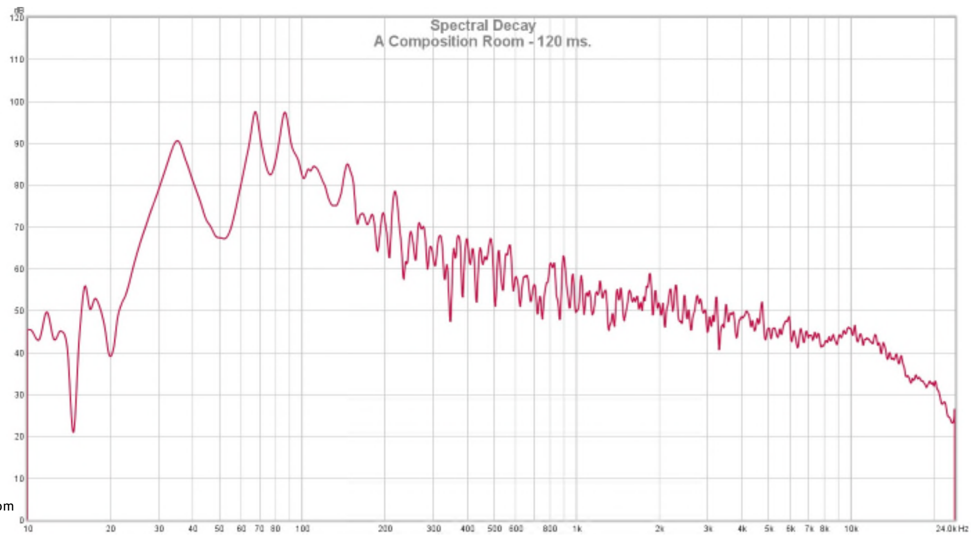
brucedblack@gmail.com

Let’s start looking at the room’s decay.

This is the same sound in the same room 60 ms. later.

It still looks ok, and everything is decaying fairly smoothly. So far, so good.

Room Absorption



brucedblack@gmail.com

But a lot of problems can happen in a very short time.

Here we are at 120 ms.

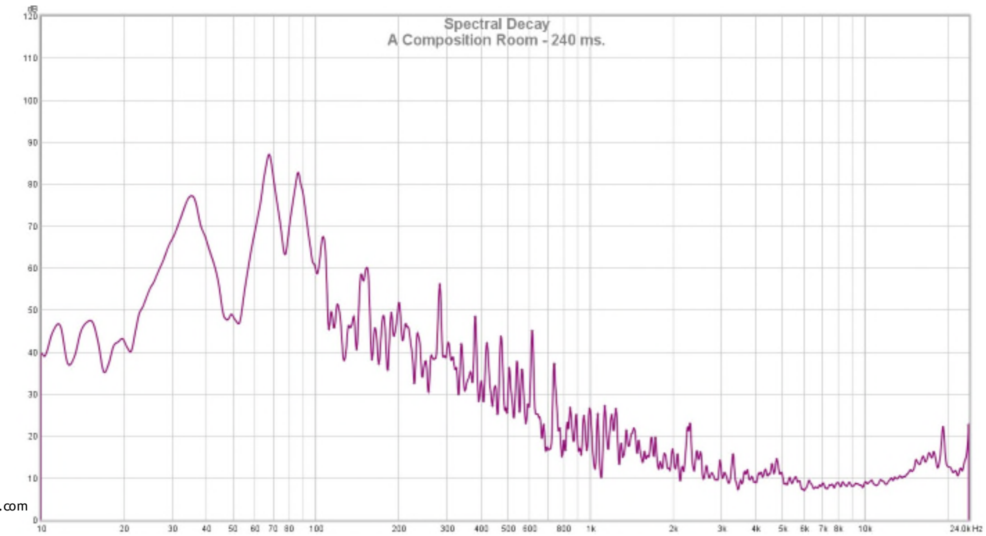
Just 60 ms. after the previous graph, we can see the dulling force of the room's excess absorption has really kicked in. The folly of making absorption our one-stop acoustical treatment becomes painfully apparent.

This is **<u>NO LONGER</u>** the flat response we saw.

In the mere 60 ms. since the last graph, the upper region has decayed 40 dB at 2 kHz. This is **<u>a lot</u>** of energy being removed from the air very quickly.

But the low frequency is holding up strongly, due in large part to the diminishing absorption below 1 kHz. This super abundance of absorption doesn't begin to touch the low end.

Room Absorption



brucedblack@gmail.com

Now we come to 240 ms.. Only a quarter of a second.

The range above 1 kHz. has been so overly absorbed that almost all that's left is the room's ambient noise. Meanwhile, the lows are still holding strong.

This is NOT a smooth decay, and graphically illustrates why overdamped rooms like this sound dead and dull, with no sense of space or "air".

In a listening situation where it's important to know exactly what is on your track, such as highly collaborative work like sound editorial for film or TV, this room will not allow you to hear your work accurately. You can miss <u>**a lot**</u> of what's going on in the track.

And in a business where you're only as good as your last job, this can impact what your next job will be.

But there is one more acoustical absorbent I almost forgot, thought by some to be infused with nearly magical properties, that can only be employed by acoustical wizards who have learned the dark arts that are denied to mere mortals.

Element 5: Room Absorption

brucedblack@gmail.com

Element 5: Room Absorption

brucedblack@gmail.com

NAAAHHHH!!

You don't want to put all your eggs in THIS basket!

Element 6: Screws Every Four Inches

brucedblack@gmail.com

Wall panels can vibrate in response to sound energy in the room's air, or that migrates through the building's structure.

These are usually the drywall or wallboard panels.

Panels vibrating from the airborne sound within the room can damage the low frequency region.

They act as resonant panel absorbers, but the frequency, width, and depth of their absorption are impossible to calculate.

Since each drywall panel is divided into multiple subpanels of different sizes by the framing and drywall screws, the absorptive response of each subpanel will vary.

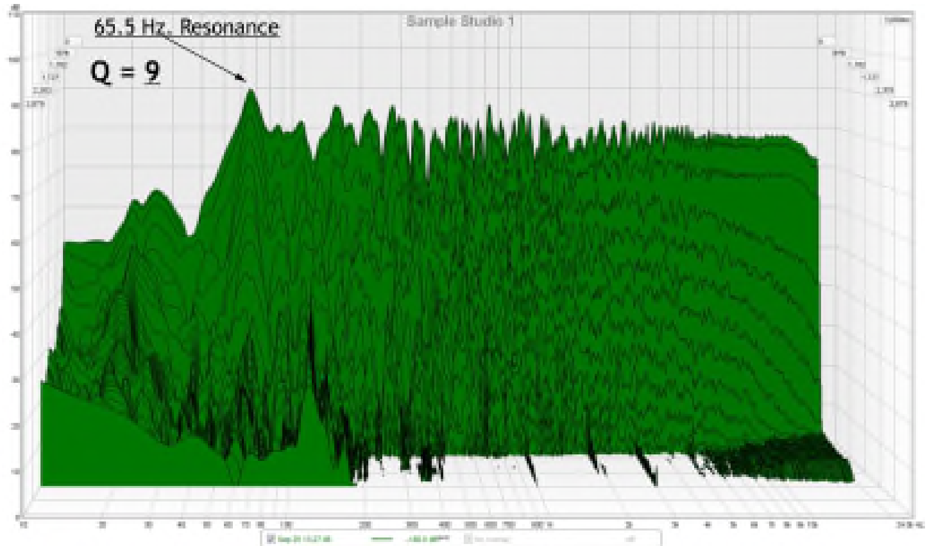
And when you combine each one with all the others, this creates a broadband low frequency absorber. If you were at my talk on low frequencies yesterday, you know why broadband low frequency absorption is problematic.

Another problem is the time it takes for the acoustic energy to overcome the panel's inertia. This means the panel's absorption will occur too late to show up in a real time analyzer's display, similar to what we saw in the last graphs.

In many studios, RTAs are the only acoustical measurement tool, so even the best engineers who hear a problem, have no way of finding out what the problem is.

So if an RTA won't show the problem, what will?

Screws Every Four Inches



brucedblack@gmail.com

A waterfall graph.

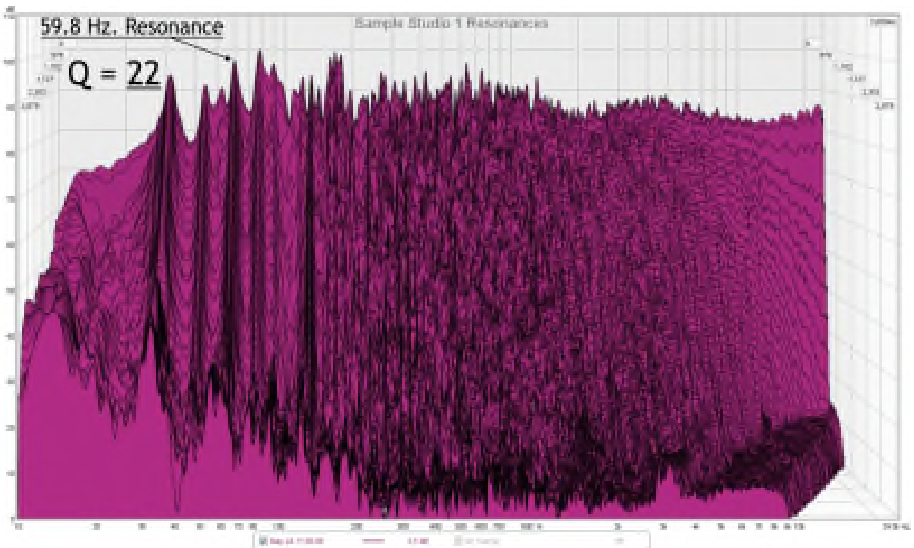
This was generated by a comprehensive acoustic analysis program.

It shows us both frequency and level, like an RTA, but it also shows us time, which an RTA can't show us.

And as we saw in the decay plots earlier, there is a lot of trouble that can hide in time.

The prominent resonance has a Q, or bandwidth, of 9, telling us that this room was built to more relaxed commercial standards.

Screws Every Four Inches



brucedblack@gmail.com

In this room, the resonances' Q is 22.
This indicates the walls are stiffer, raising the Q.

In building this room, the contractor **did** use 4 inch screw spacing.
If he hadn't, the Q wouldn't be this sharp.

This also brings to light a pitfall of building an unpermitted acoustical space. An unsavory contractor may use as few screws as possible; perhaps just enough to keep the panels from falling. Once the wall is finished and painted, there's no way to check their screw spacing.

And there's no building inspector to catch it for you either.

Meanwhile, U.S. building code specifications can range up to a maximum spacing of 16 inches between screws, depending on the circumstances. But they're not concerned with acoustical performance.

So even in compliant construction, you can still be left with walls that vibrate a lot, damaging your low end.

And this is important, because, like I've been known to say frequently, the low frequency region is where the bulk of sonic quality is perceived.

Element 7: No Bass Traps

brucedblack@gmail.com

No bass traps??? More of my blasphemy!

Bass traps are broadband devices that attenuate **everything** in their range.
They lower the peaks that you want to reduce, but they also affect low frequencies that should be left alone.

And any dips get reduced further.

Many folks add them because that's just what you do. Without regard for if they really need some treatment in the low end or not. This is just blind acoustical treatment, without any informed data to illuminate and guide the way.

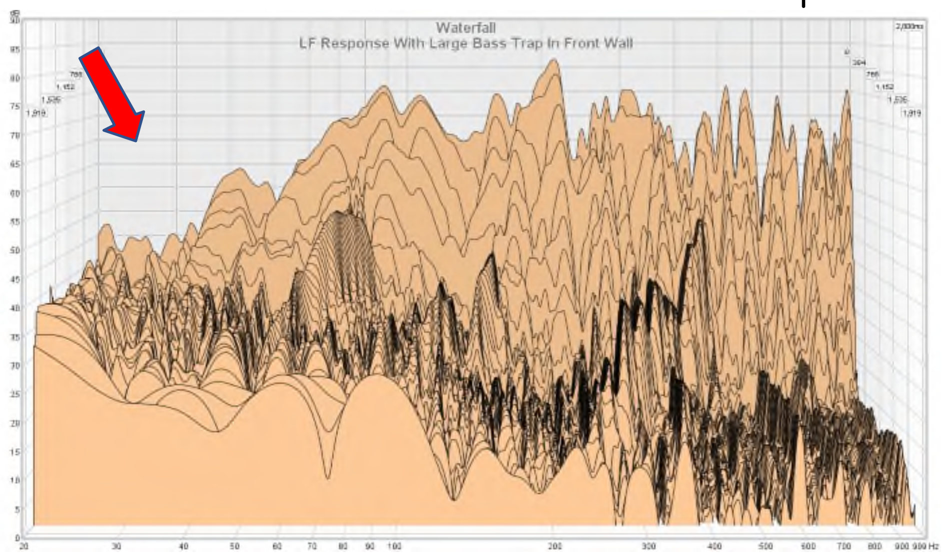
On the other hand, Helmholtz resonators can selectively reduce specific low frequencies to allow a more precise control over them.

These are narrow band devices that can be focused on the problem frequencies, treating **them** while leaving everything else intact. This gives you a more accurate low end.

Some may think EQ makes all this unneeded, but in the end, it is **far, far** better to optimize the room acoustically first.

So what can go wrong using bass traps?

Element 7: No Bass Traps



brucedblack@gmail.com

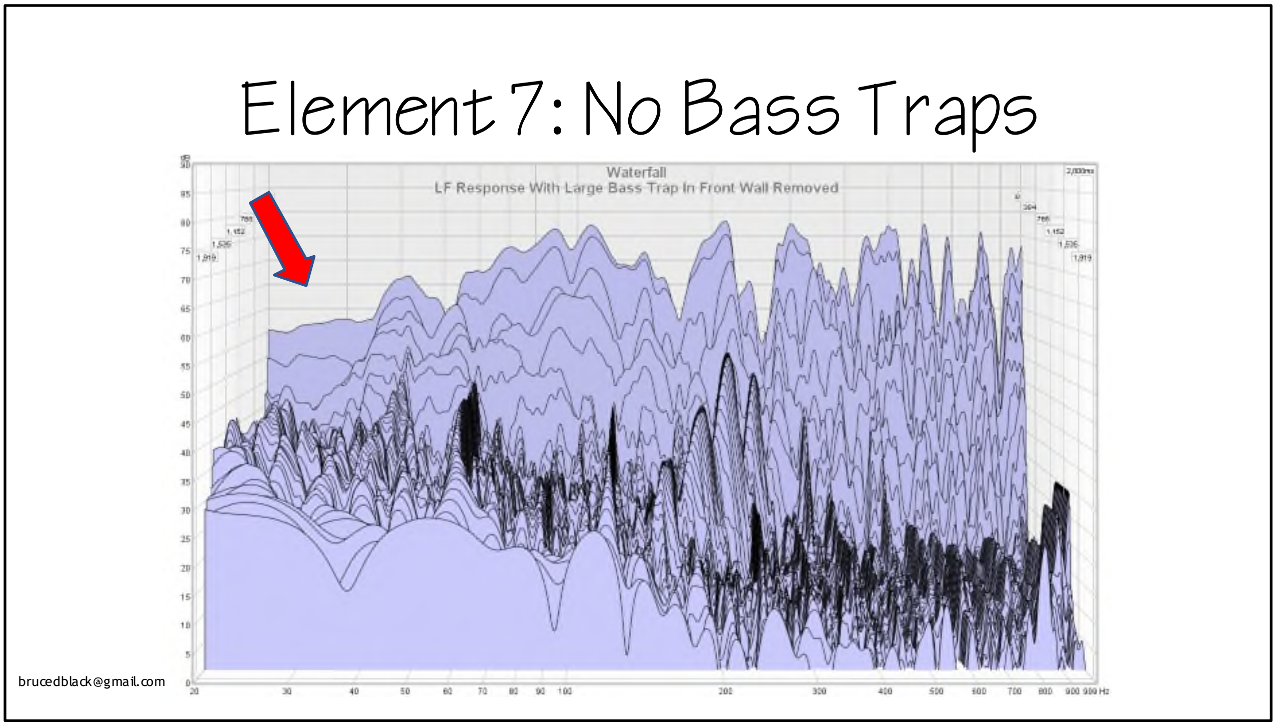
This is the waterfall graph of a music mix room, showing 20 Hertz to 1 kilohertz. An acoustic analysis provided this.

The mixer complained that everything below 100 Hz. seemed to be missing.
Even just a quick glance reveals that yes, the low end is seriously rolled off., starting just below 100 Hz.

Specifically, a sharp roll off below 90 Hz., at 24 dB per octave.

It turned out that the room had an 18 inch deep fiberglass filled cavity in the front – a classic bass trap.

Once it was removed, we got this --



Here we see that much of the low frequency is restored, and the punch, or **physical** experience of the low end instruments on recordings is now audible.

Just by ***removing*** a poor choice of acoustical treatment.

This is why I don't like using bass traps, and prefer a more precise, surgical approach to low frequency control.

With the way bass traps work, you can't control how they act.

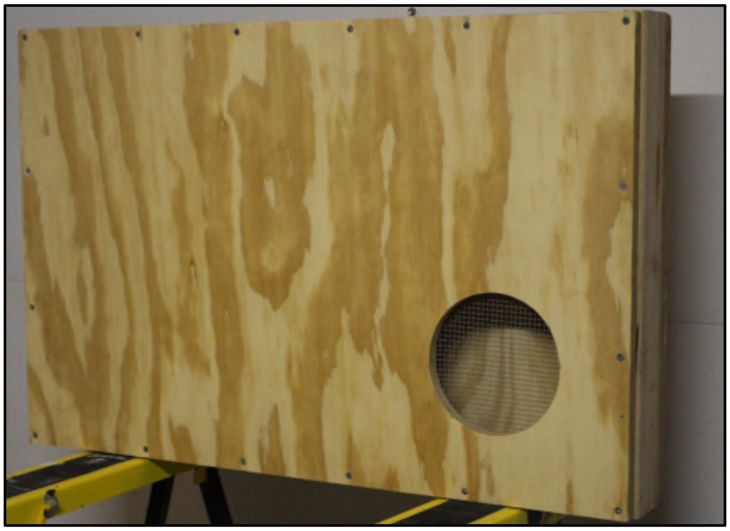
You can't tune them to focus on a specific problem, and it's difficult to control how much they absorb.

So there is no way to foresee how they will affect the room's sound.

And if this is a room people depend on for their livelihood, isn't it imperative that we have a precise idea of how it's going to perform?

Especially since a large part of our perception of sonic quality is determined by the low frequency?

Element 7: No Bass Traps



brucedblack@gmail.com

This is a Helmholtz Resonator.

As you can see, it is a simple device – two pieces of ¾ inch plywood mounted on a 2 X 4 frame with a hole in it.

It's like a ported speaker cabinet with no speaker. This is a great tool for low frequency control.

The box can be any size, so it can be proportioned to fit into any available open space you have. Whatever size you make this, you can tune this to the frequency needed by adjusting the port size to the volume of the box.

While you have some latitude in where you can place these, they work best when the port is within a high pressure zone, with the port facing a wall, and 1 or 2 inches away from it.

In mix rooms and control rooms, they can be hidden quite nicely behind the client sofa. This puts the resonator in a good high pressure zone, and moves the clients out of it some, making their listening experience less boomy and more accurate.

In this unfinished "natural state", it doesn't fit well in a studio where special attention was paid to looks, like Woodshed Recording from earlier.

But since the active part is the port, which will be facing the wall anyway, you can finish this with paint, fabric, oiled hardwood veneer, whatever.

As long as you build it to be rigid, and don't cover or otherwise impede the port, this will perform well.

To treat the low frequency range, you tune a set of these to the offending frequencies.

You then adjust the amount of attenuation by the number of resonators at each frequency.

All this begs the question – how do you know if you need low frequency treatment, and what frequencies to use if you do?

This brings us to the next essential element.

Element 8: Acoustic Analysis

brucedblack@gmail.com

You need detailed, real world data on how your room is performing in order to know how to treat it. Not guesswork or useless things like hand claps.

And Real Time Analyzers give you almost no information that you can act on, so how can we find out what the acoustical issues in a room are?

I've been known to belabor the importance of treating a room using **real** data based on what is **actually happening** acoustically. This comes from an acoustical analysis.

This gives you the data you need to select, position, and tune the various treatments based on the real-life environment's data, not guesswork, or even potentially inaccurate calculations.

This data provides the difference between, "Well, it feels like it's kinda boomy", and "There are two 18 dB peaks – one at 32.5 Hz. and one at 65 Hz."

The first approach is not specific, so for low frequency problems, the best you can do with this vague information is install a bass trap. And hope it helps, without damaging the rest of the low end. Unlikely. It's really just hit-and-miss.

The second provides detailed information that allows you to install sets of resonators precisely at each errant frequency.

This approach flattens out the low end, while preserving its integrity.

And an acoustic analysis is what gives you the precise information you need to do all that.

Element 8: Acoustic Analysis

brucedlack@gmail.com

It starts by the analysis software playing back a special test signal.

The reliable results we need come from equipment with good performance.

So the speaker should have a flat frequency response, with a low frequency roll off as low as possible.

It also needs to have wide, flat dispersion, so that you're exciting the room evenly.

These conditions minimize the influence of the equipment on the resulting data –

You want to see what the **<u>room</u>** is doing, not the test equipment.

Element 8: Acoustic Analysis

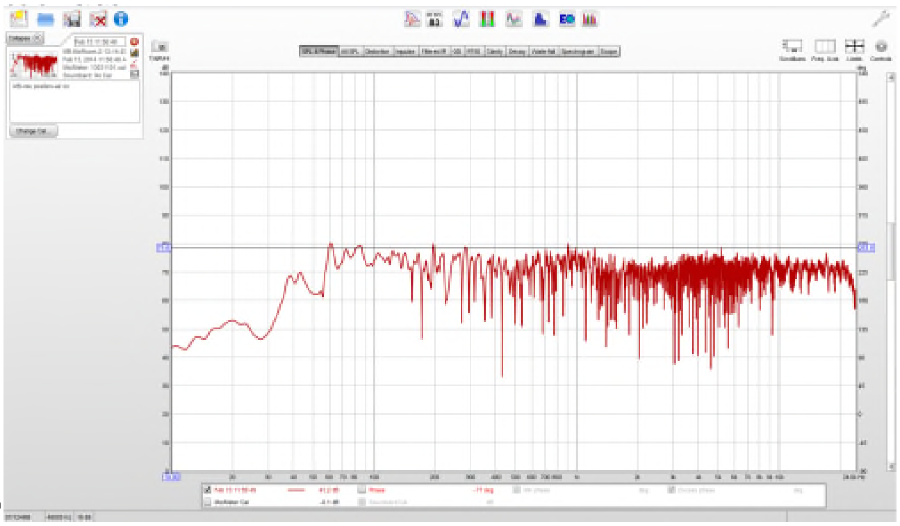
brucedblack@gmail.com

This sound is then picked up by a measurement microphone and recorded as a data file in the computer.

The mic should also be as flat as possible, and come with a calibration file to plug into your software.

It is placed in and around the various listening positions, such as the mix position, the producer's position, and the client sofa, taking multiple measurements.

Element 8: Acoustic Analysis

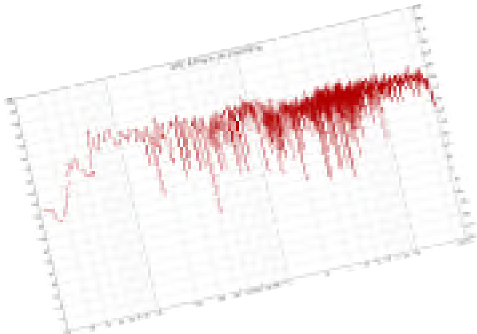


brucedblack@gmail.com

This data is then crunched by the software, which provides you with graphs that reveal different aspects of the room.

Some of you may recognize this as Room EQ Wizard, which is my preferred analysis software. There are other software packages available, like Smaart.

Element 8: Acoustic Analysis



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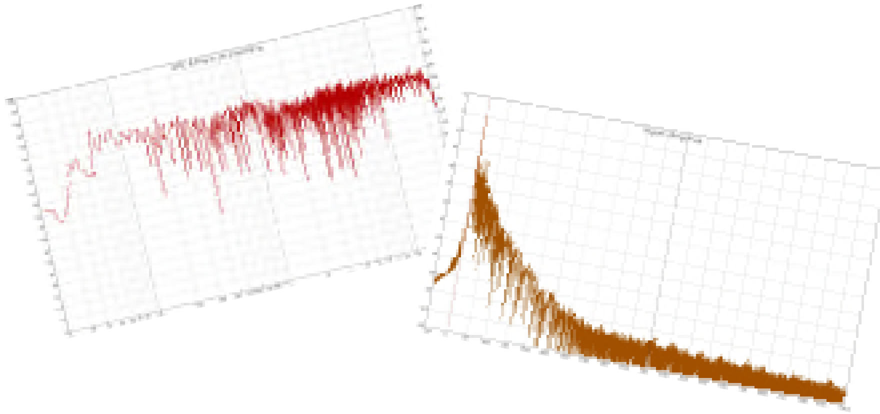
You can look at the frequency domain with the frequency response graph…

Element 8: Acoustic Analysis



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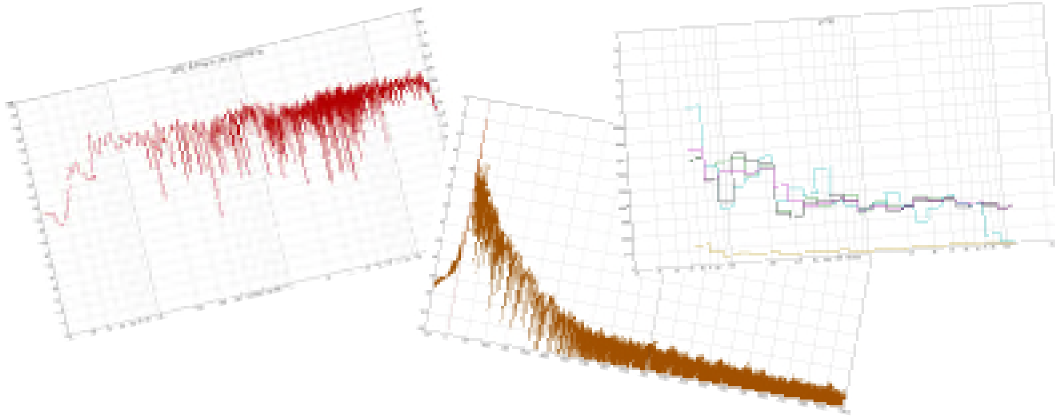
… and you can look at the time domain and reflections with the impulse response graph.

Element 8: Acoustic Analysis



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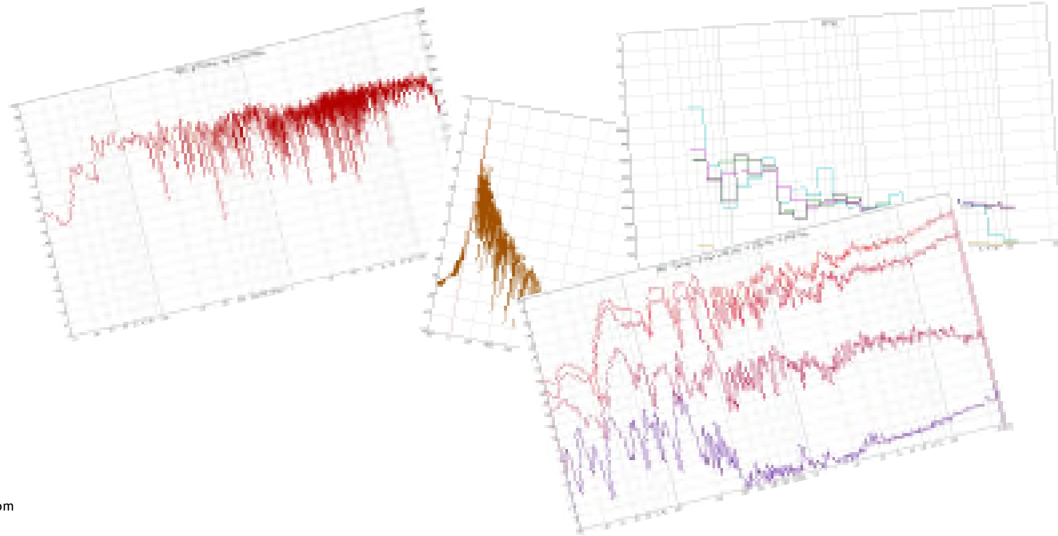
You can see what the reverberation time is, broken down into frequency bands…

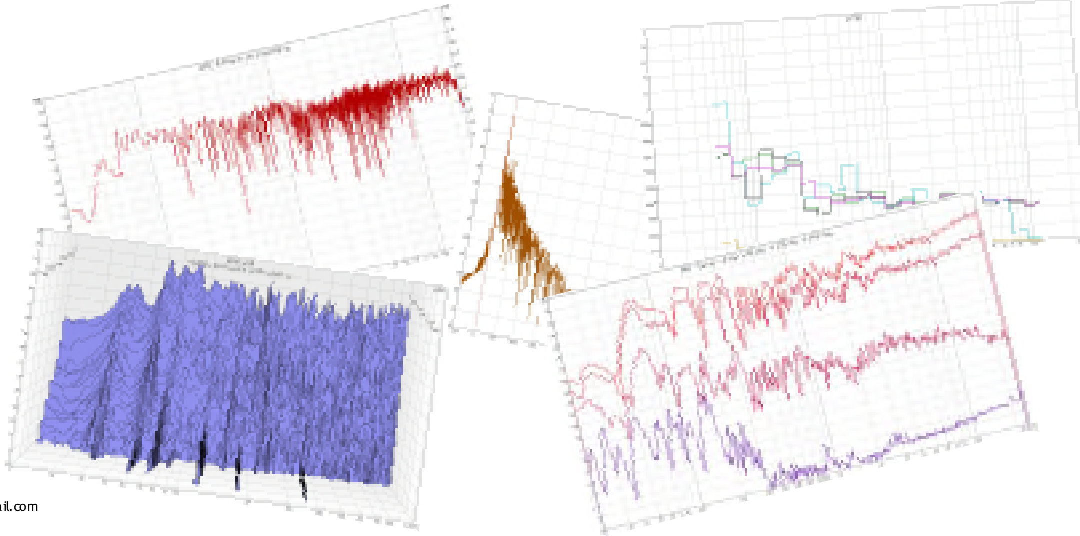
Element 8: Acoustic Analysis



brucedblack@gmail.com

…you can see how the room's response changes over time, with decay plots, like we looked at earlier…

Element 8: Acoustic Analysis



brucedblack@gmail.com

…and see a bunch of information at once, with the waterfall plot, also seen earlier.

One way or another, all the important acoustical characteristics of a room are revealed.

We're close to the end, but there's one more Essential Element you need…

Element 9 – A Good Contractor!

brucedblack@gmail.com

Lastly, all the hard work designing your masterpiece room can be lost if the contractor doesn't build it the way you designed it.

If they take short cuts, thinking you'll never know once everything is hidden under a layer of drywall or fabric, your room will not perform to expectations.

And if they make careless mistakes, you'll end up with some serious problems that will be expensive and time consuming to fix.

Obviously, this is not good, especially if your have clients that have scheduled a project to start work in your new room on a specific date.

So choose your contractor carefully, making sure they understand that all those seemingly unimportant, wasteful things are in fact **required** to get the highest performance. We're not building a simple room addition or remodeling a kitchen.

Studio construction demands careful attention to details, and proper techniques, quality materials, and expert workmanship. Not every contractor can do it. They need to have experience in it, or be committed to following your design down to the finest details. And they need to ask any question they have and not be shy or guess.

If they also understand that your testing of the finished room will reveal any shortcuts they take, and that they will be expected to correct them, they should apply themselves conscientiously.

Then inspect often.

That's It!

brucedblack@gmail.com

So there you have it.

These are the nine elements that will bring you a successful conclusion to building **any** studio or acoustically sensitive space that performs exceptionally well.

Thank you for attending. I think we may have some time for questions.

If you'd like to stay in touch, leave your business card up front here.

There are also some of my business cards with a source for Sorbothane that is offering a 15% discount.