Acoustic Fields

ACOUSTICS GUIDE

OVER 20 PRINCIPLES OF ROOM ACOUSTICS EXPLAINED

DENNIS FOLEY

Acoustics Guide

Over 20 Principles of Room Acoustics Explained

Small room acoustics are difficult. It involves sound pressure, reflections, vibrations, room size and volume along with a myriad of other variables. All of these variables are based in the science of physics which next to chemistry is the most difficult of all the physical sciences to understand, comprehend, and more importantly implement correctly when it comes to our audio presentations whether two channel playback, home theater, and mixing/mastering/vocals for professional applications. To assist us with this comprehension and understanding of complex physical science issues in small room audio acoustics, we turn to pictures or graphics.

The graphics that follow, illustrate issues that are basic ones that need to be grasped and understood first and foremost before one can even think about designing or building your own audio room. They illustrate complex physical properties that must be understood in order to facilitate a next level of understanding that is required in any audio room build. First, read the text for overall comprehension and understanding. Secondly, study the graphic as a symbol or representation of the text. Together they will serve you well is your understanding of the physical science relationships that are critical in all small room audio applications.

Kind Regards,

Dennis Foley

Dennis Foley
Owner & Inventor of Acoustic Fields

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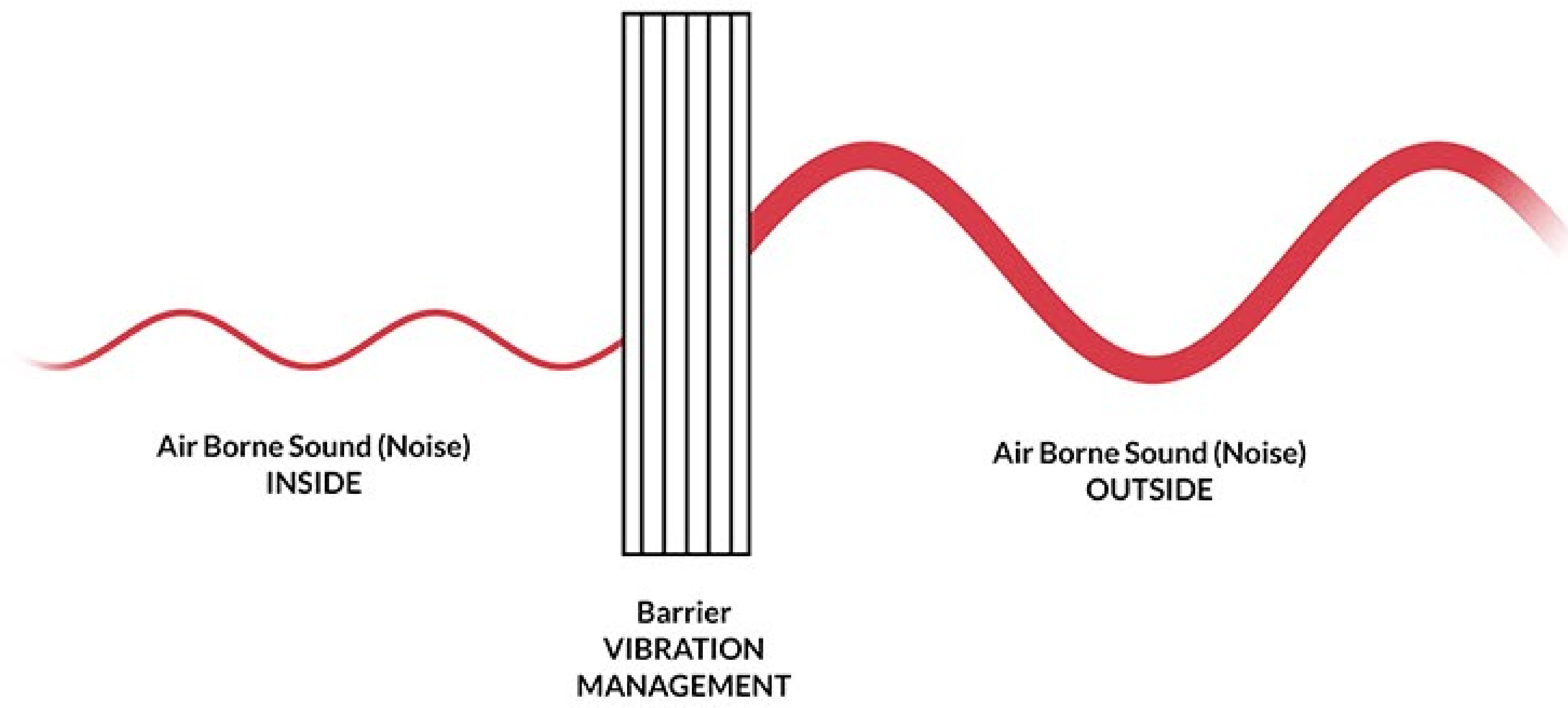
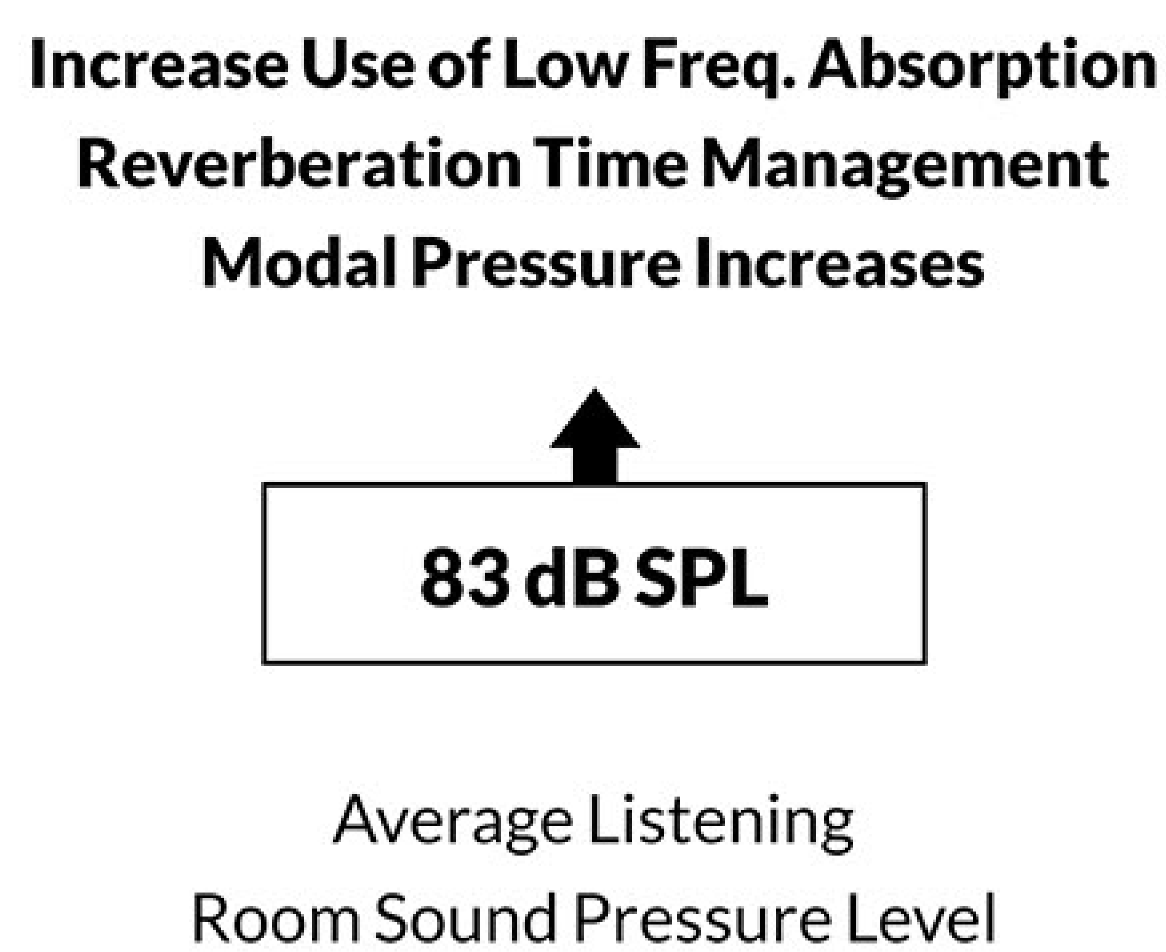
1. Air Borne Energy

Most of what we hear as sound travels through the air. Air born energy has its own set of laws of physics. Once the air born energy strikes a surface or solid object, it now becomes vibration energy and must obey a new set of laws which are similar to air born but different. It is the understanding of those frequency and amplitude differences that make for a successful barrier against noise transmission.



2. Average Listening Room Sound Pressure Level

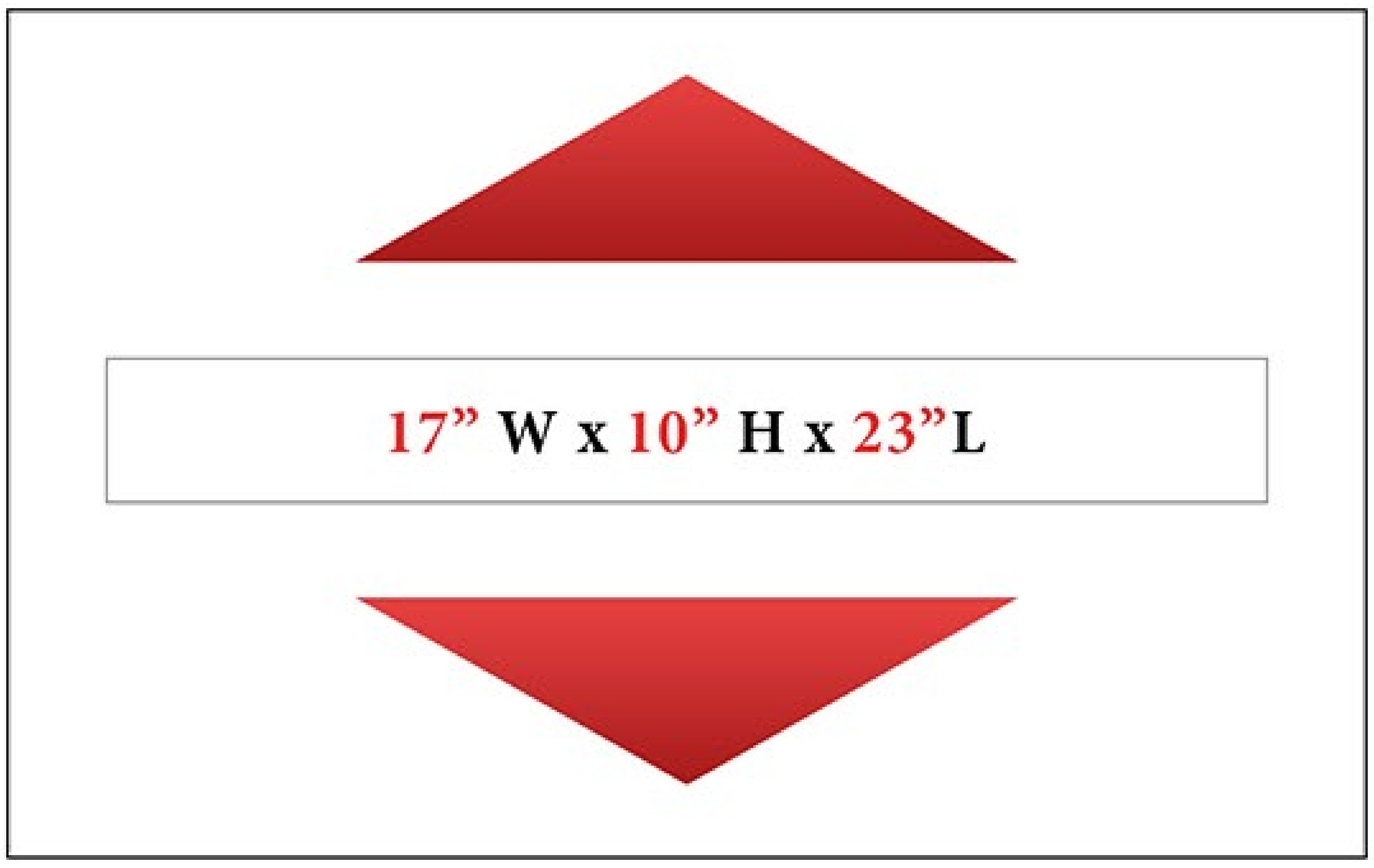
The average listening level in most audio rooms whether just two channel playback mixing or mastering is 83 dB SPL. Use this number as a guideline when lowering RT-60 times, maximizing the amount type and location of low frequency absorption technologies and any other acoustic parameter that needs an out put level.



3. Best Room Ratio

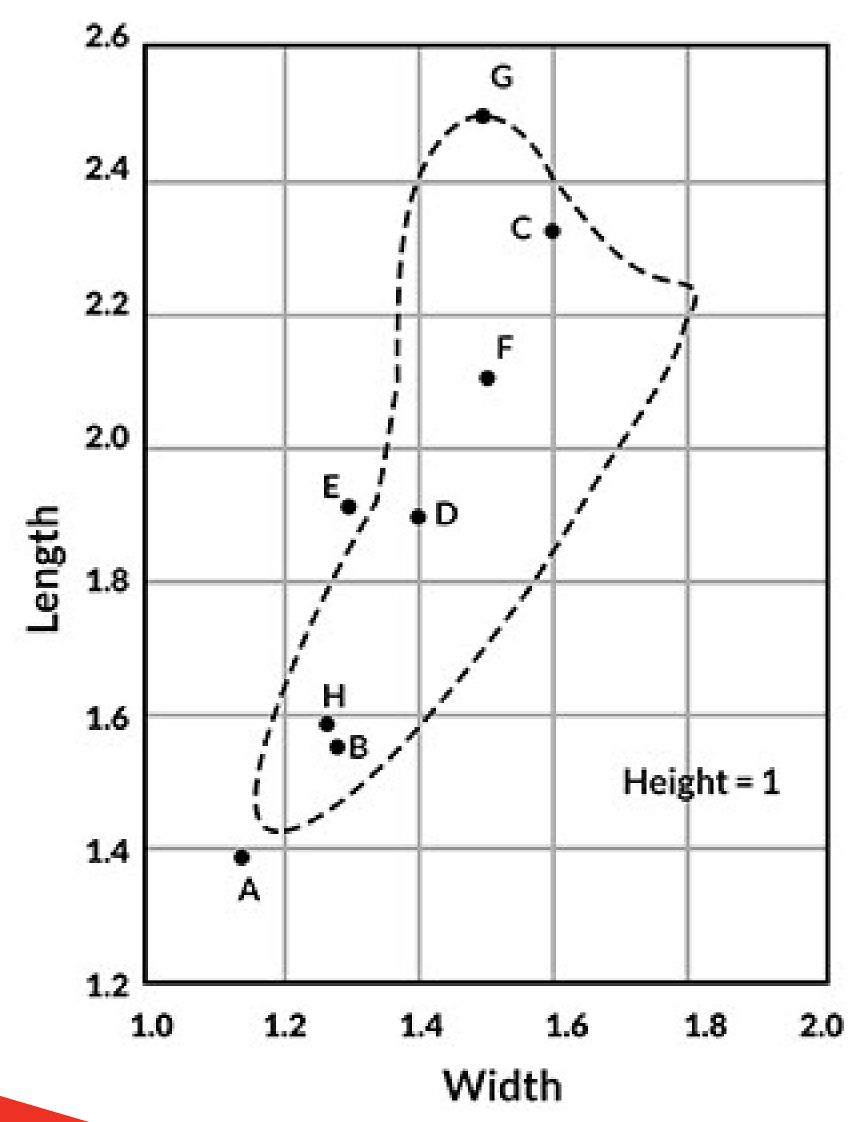
Starting with the correct room size and volume that matched usage is the most important first step in any audio room design. Starting with the size that reduces unwanted modal pressures and allows for proper reflection management will go along way for you as your room moves forward. This size below is a good start size. Larger is better but this minimum size allows for enough space to treat the low frequency issues correctly and enough side wall distance to properly manage the time signature of reflections.

Best Room Ratio



4. Room Size & Volume Charts

Room size and volume charts are available from many engineers and studio builders. These are all charts and graphs that have been around for years. They are a starting point but you don't want to rely on them completely. They do minimize low frequency issues in the "just room" size and volume without any consideration for absorption technology / treatment and the space requirements to treat. Every small room needs low frequency energy management and it takes a lot of surface to impact room response. Most of the charts and graphs showing "correct" room widths, heights, and length ratios are based upon modal band widths that are too large for today's high resolution digital formats. They worked well in the past, but times have changed.



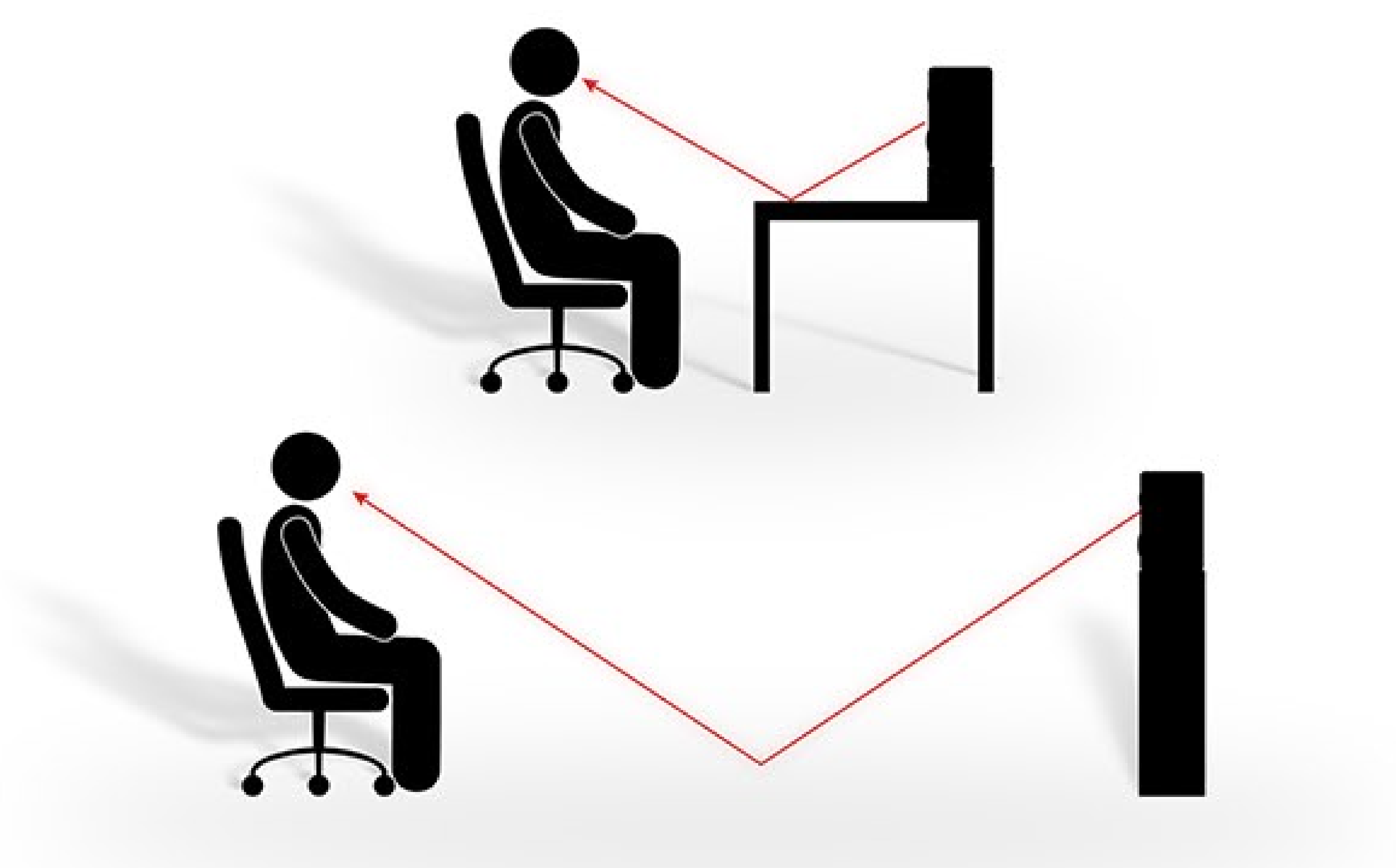
5. Good Room Size and Volume Chart

Room size and volume are critical in our audio rooms. We must start with a minimum volume and distance to accommodate first low frequency waves and then middle and high frequency rays. Starting with certain room sizes and volume will go a long way to minimizing the amount of treatment required as you move down the road towards the tuning of your room. Starting with a minimum size and volume will also assist you with lower treatment costs. This table offers some good starting points with the red area a no go acoustically and the yellow problematic with treatment.

W	H	L	cu.ft.	m^3
9' | 2.43m	11' | 3.35m	10' | 3.04m	990	24.75
10' | 3.04m	11' | 3.35m	11' | 3.35m	1210	34.12
11' | 3.35m	11' | 3.35m	12' | 3.65m	1452	40.96
12' | 3.65m	11' | 3.35m	13' | 3.96m	1716	48.42
13' | 3.96m	11' | 3.35m	14' | 4.26m	2002	56.51
14' | 4.26m	11' | 3.35m	15' | 4.57m	2310	65.21
15' | 4.57m	11' | 3.35m	16' | 4.87m	2640	74.55
16' | 4.87m	11' | 3.35m	17' | 5.18m	2992	84.51
17' | 5.18m	11' | 3.35m	18' | 5.48m	3366	95.09
18' | 5.48m	11' | 3.35m	19' | 5.79m	3762	106.29
19' | 5.79m	11' | 3.35m	20' | 6.09m	4180	118.12
20' | 6.09m	11' | 3.35m	21' | 6.40m	4620	130.56
21' | 6.40m	11' | 3.35m	22' | 6.70m	5082	143.64
22' | 6.70m	11' | 3.35m	23' | 7.01m	5566	157.33
23' | 7.01m	11' | 3.35m	24' | 7.31m	6072	171.66

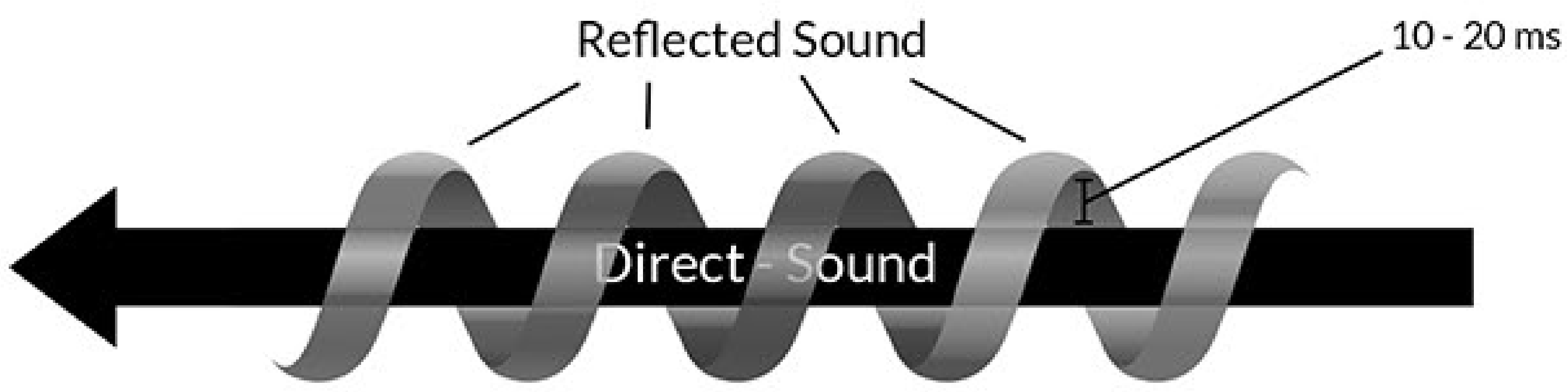
6. Floor and Ceiling Reflections

Floor and ceiling reflections strike our listening positions first. These two surface areas are the closet to the listener. Ceiling reflections can impose a shrinking effect on our sound stage. The ceiling reflection intermixes with the direct sound from our speakers and produces this quashing effect. You can hear a low ceiling every time in a mix or presentation. Treatment options are absorption/diffusion or a combination of both depending on usage.



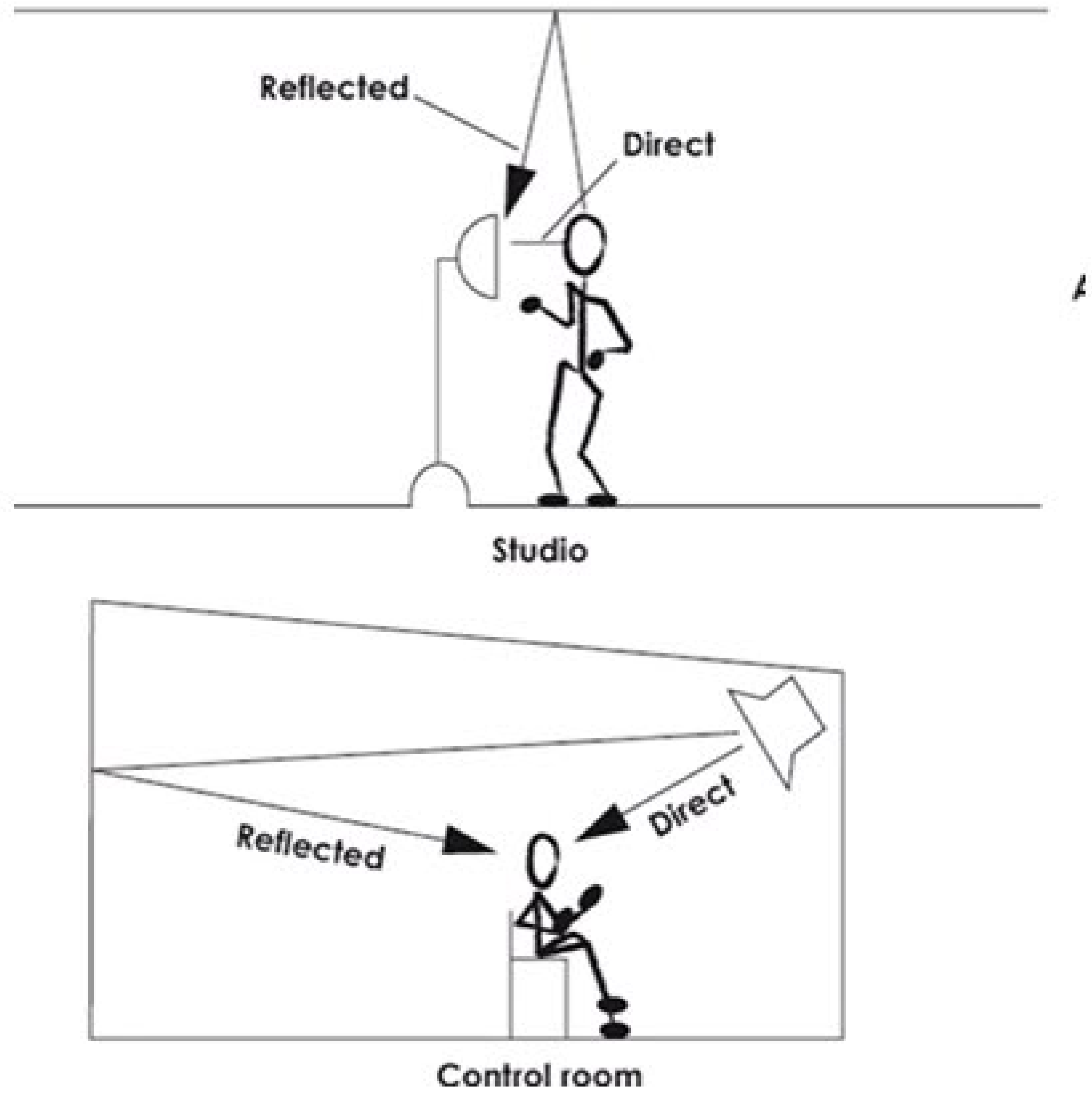
7. Direct & Reflected Energy

Direct energy is the straight line energy from our speakers. It is the energy that travels in a straight line from our speakers to our ears. Reflected energy is direct energy striking the room boundary surfaces and then intermixing with the direct energy. Both the direct (speaker) and reflected (room) sound accounts for the total sound and its quality that we hear. Near field monitoring is a way to minimize room sound and maximize direct sound.



8. Direct & Reflected Sound

The sound we hear in a room is a combination of the direct sound or straight line sound from our speakers and the reflected sound energy from our room boundary surfaces. Ceiling and floor reflections reach our ears and microphones first since they are physically the closest surfaces to our ears or microphones. It is the balance of the direct and reflected energy that produces the sound we hear. All audio rooms must take into account both direct and reflected energy in both producing and recording music.



9. Notes & Frequency Chart

All musical notes have a frequency assigned to them. Music is produced at each note with the oscillation of some type of membrane at a particular frequency. Each instrument that produces music has a particular frequency response associated with it. Drums are full range where tuba's are more restrictive in the frequency range they represent. These charts represent the notes played by an instrument and the frequencies they represent.

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Notes & Frequency

NOTES	0	1	2	3	4	5	6	7	8
C	16.35	32.70	65.41	130.81	261.63	523.25	1046.50	2093.00	4186.01
C# / Db	17.32	34.65	65.41	138.59	261.63	554.37	1108.73	2217.46	4434.92
D	18.35	36.71	73.42	146.83	293.66	587.33	1174.66	2349.32	4698.63
D# / Eb	19.45	38.89	77.78	155.56	311.13	622.25	1244.51	2489.02	4978.03
E	20.60	41.20	82.41	164.81	329.63	659.25	1318.51	2637.02	5274.04
F	21.83	43.65	87.31	174.61	349.23	659.25	1396.91	2793.83	5587.65
F# / Gb	23.12	46.25	92.50	185.00	369.99	739.99	1479.98	2959.96	5919.91
G	24.50	49.00	98.00	196.00	392.00	783.99	1567.98	3135.96	6271.93
G# / Ab	25.96	51.91	103.83	207.65	415.30	830.61	1661.22	3322.44	6644.88
A	27.50	55.00	110.00	220.00	440.00	880.00	1760.00	3520.00	7040.00
A# / Bb	29.14	58.27	116.54	233.08	466.16	932.33	1864.66	3729.31	7458.62
B	30.87	61.74	123.47	246.94	493.88	987.77	1975.53	3951.07	7902.13
DISTANCE (ft.)	0	1	2	3	4	5	6	7	8
C	69.3	34.65	17.32	8.66	4.33	2.17	1.08	0.54	0.27
C# / Db	65.42	32.7	17.32	8.18	4.33	2.04	1.02	0.51	0.26
D	61.74	30.86	15.43	7.72	3.86	1.93	0.96	0.48	0.24
D# / Eb	58.25	29.13	14.57	7.28	3.64	1.82	0.91	0.46	0.23
E	55	27.5	13.75	6.87	3.44	1.72	0.86	0.43	0.21
F	51.9	25.96	12.98	6.49	3.24	1.72	0.81	0.41	0.2
F# / Gb	49.01	24.5	12.25	6.12	3.06	1.53	0.77	0.38	0.19
G	46.24	23.12	11.56	5.78	2.89	1.45	0.72	0.36	0.18
G# / Ab	43.64	21.83	10.91	5.46	2.73	1.36	0.68	0.34	0.17
A	41.2	20.6	10.3	5.15	2.58	1.29	0.64	0.32	0.16
A# / Bb	38.88	19.44	9.72	4.86	2.43	1.22	0.61	0.3	0.15
B	36.7	18.35	9.18	4.59	2.29	1.15	0.57	0.29	0.14

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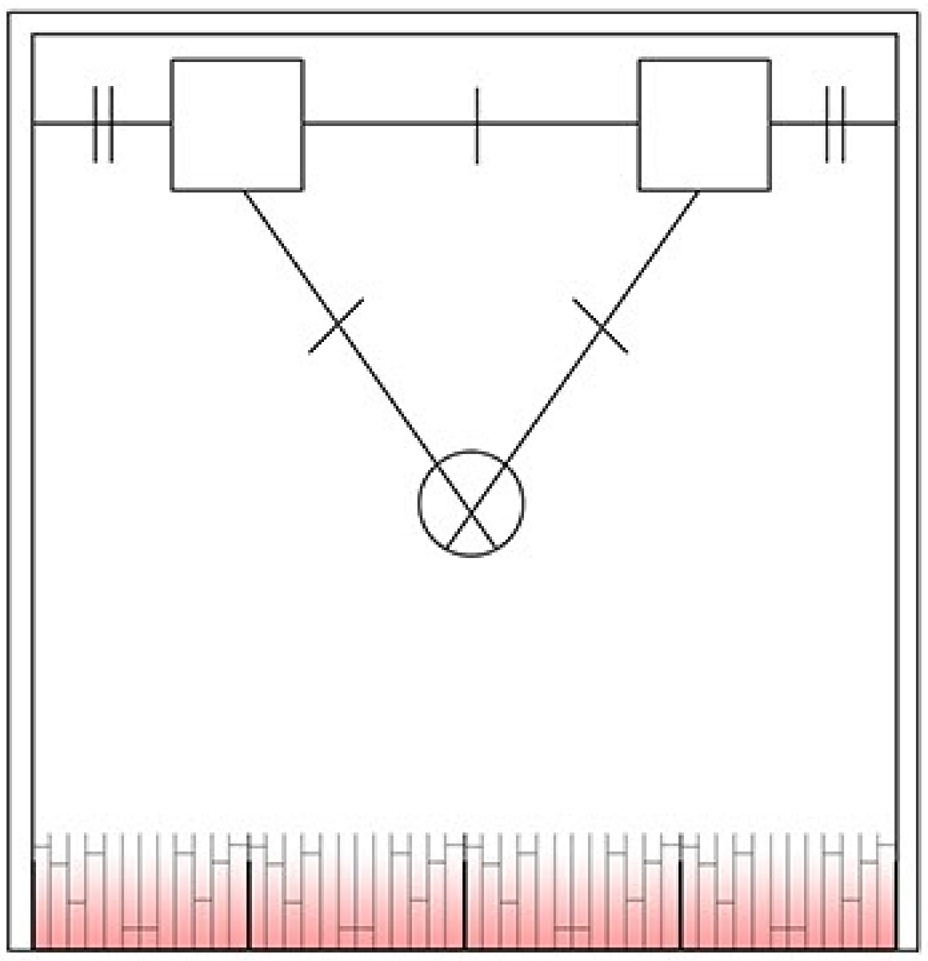
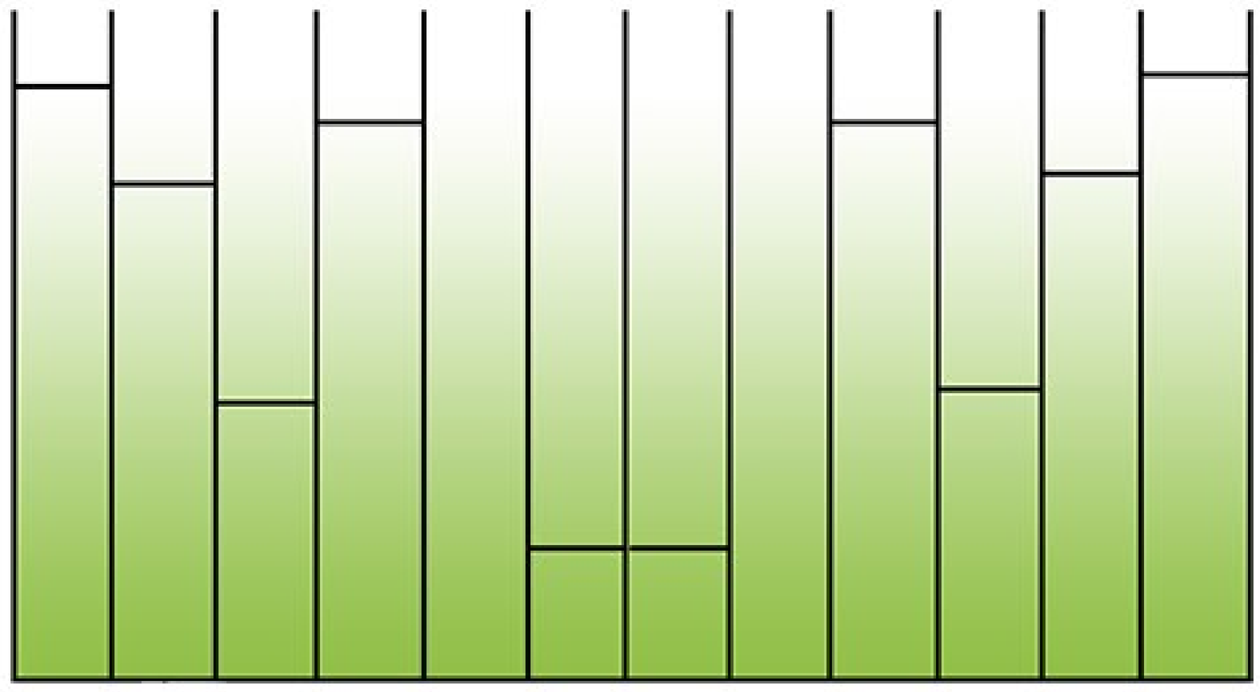
10. Dealing With Rear Wall Reflections

Reflections from room surfaces intermix with the straight line or direct energy from loud speakers. Our acoustic goal is to achieve a mix between the direct and reflected energy. Reflections from the rear wall are problematic at the mix position where accuracy is critical. We want to hear what is in the mix and not in the room. This phenomenon can be addressed using quadratic diffusion spread across the rear wall surfaces.



11. Rear Wall Diffusion

Rear wall diffusion is popular in two channel mixing and playback. Diffusion sequences must match and cover the entire rear wall surface area. Front wall diffusion is also welcome in two channel playback rooms. You must choose a diffusion sequence that works with the distance you have to your listening position. You need distance for the lowest octave represented by the diffuser sequence to exit the diffuser and fully form.



12. Control Room Rear Wall Diffusion Tips

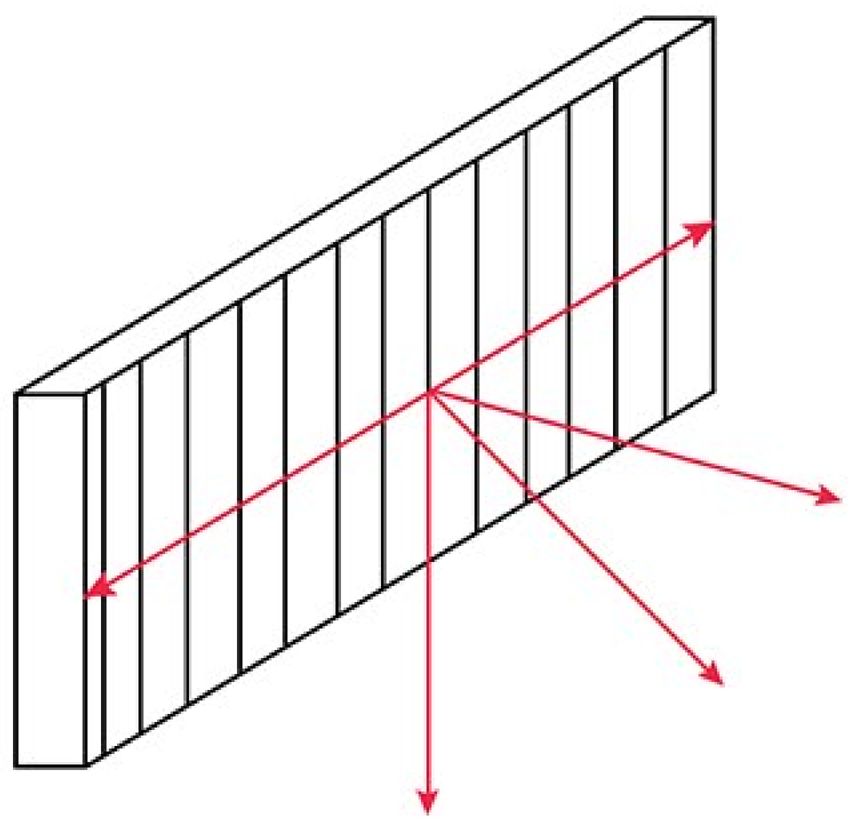
After visiting hundreds of studios over my 40 years in this business, I see certain patterns in acoustical treatment. I also hear the end product the studio produces. Of all the product I hear, the ones that consistently produce good sounding recordings have quadratic diffusion on the rear wall of the control room. Here is a list of what I have learned to be minimums when it comes to the diffusion sequence, orientation, and surface area coverage.

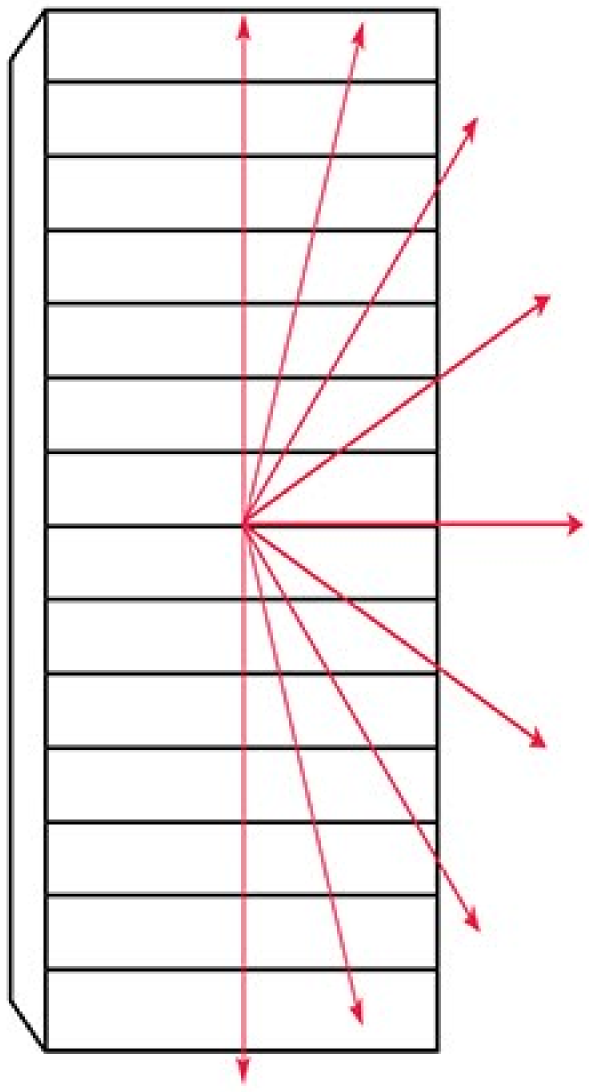
Control Room Rear Wall Diffusion Tip

- Always use a quadratic diffuser with a prime number of 13 or higher
- This will require a space of 13” minimum and a 6’ distance from rear wall to listening position
- Always use quadratic diffuser in vertical position

13. Vertical & Horizontal Diffusion

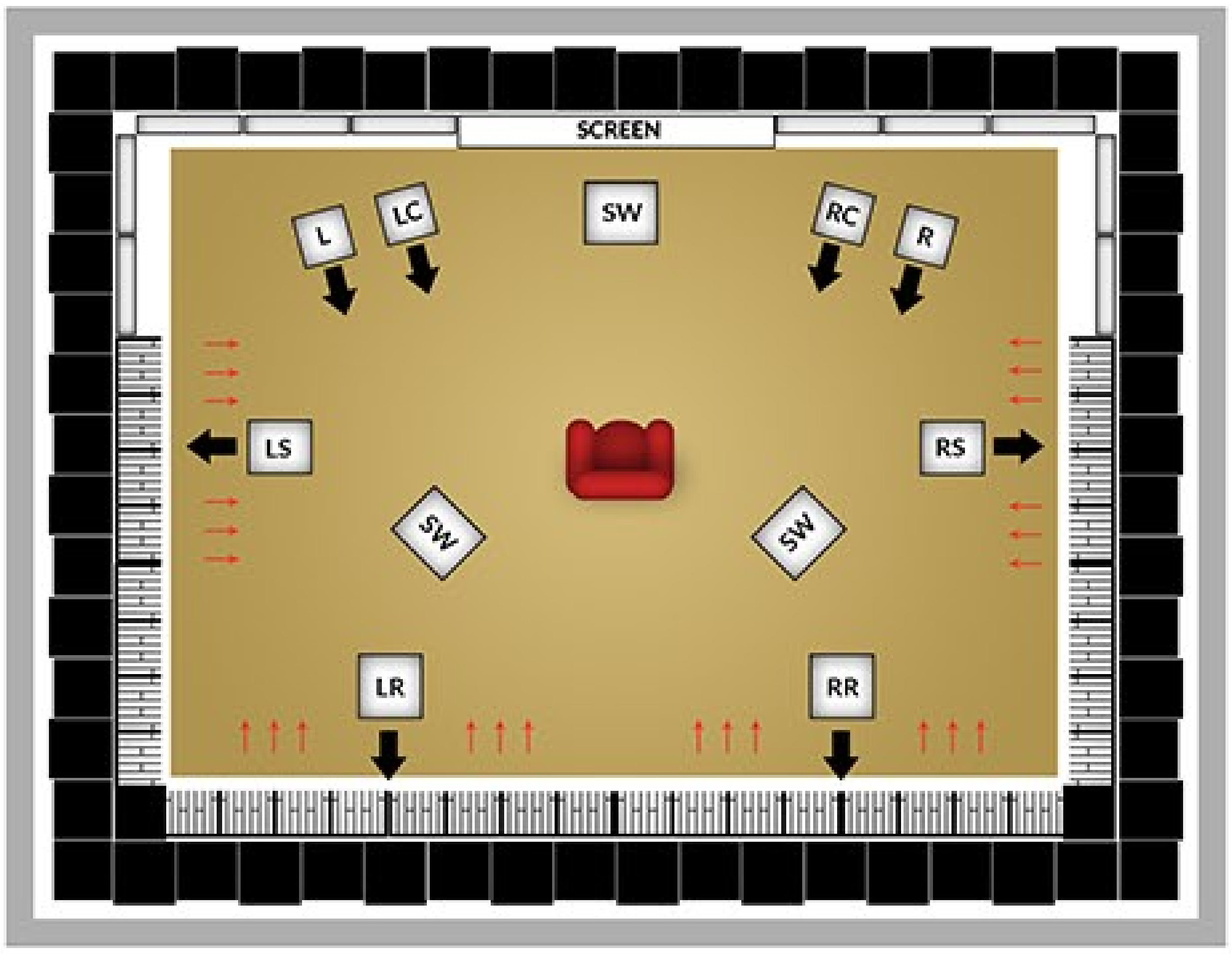
Quadratic diffusers are vertical and horizontal in their physical orientation. A vertically positioned diffuser diffuses sound in a horizontal direction. A horizontally positioned diffuser positions sound in a vertical direction. Using both types can produce two dimensions of diffusion when needed. It is the understanding of this energy radiation into our rooms that enables us to psycho acoustically lessen the impact that reflections have upon our ears and brains at the listening position.





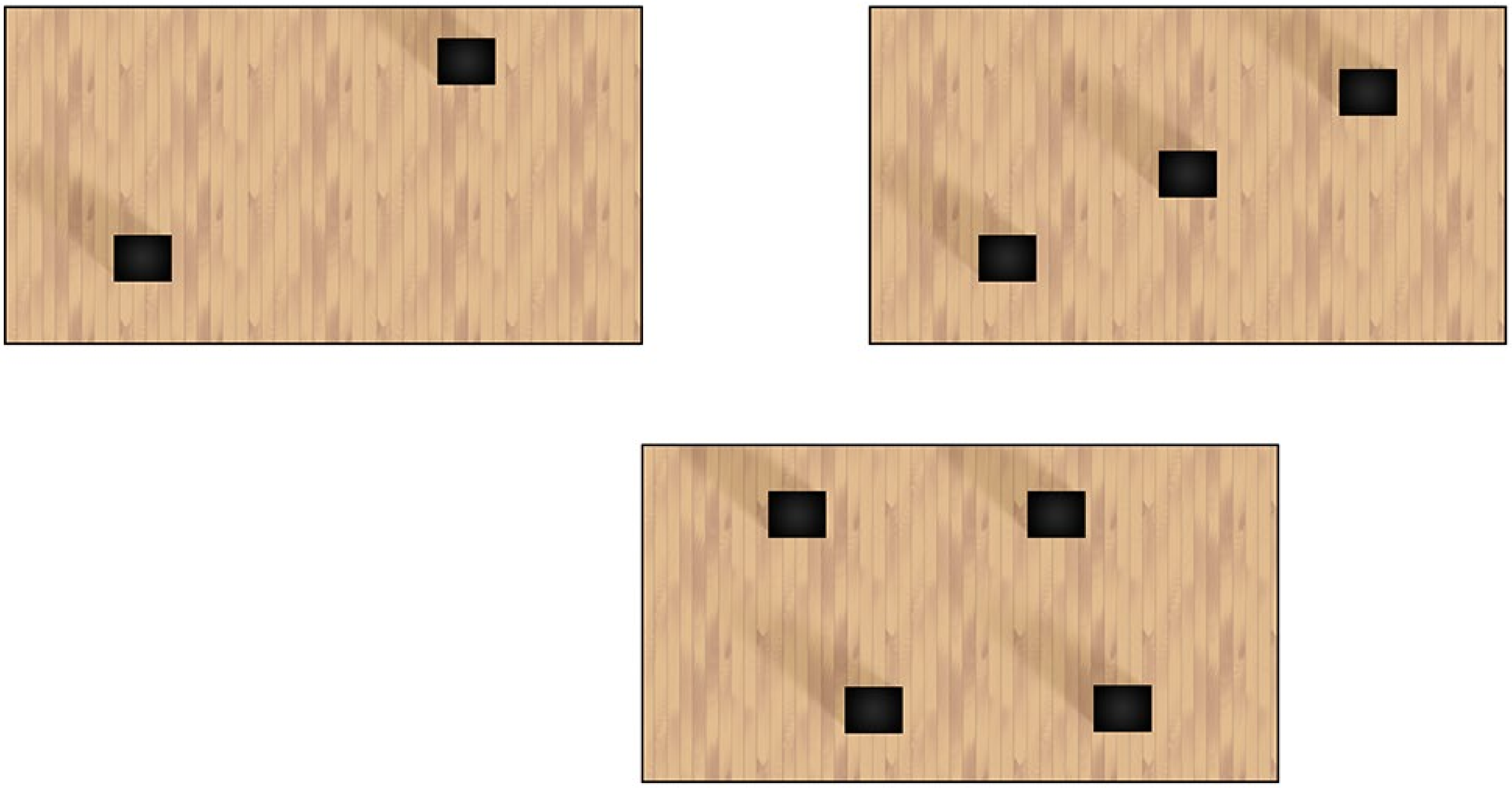
14. Home Theater Applications

Home theater applications such as 5.1 and 7.1 have multiple channels that emit sound energy into the room. Standard installation techniques show that all channels directly fire into the room. The method depicted in this video shows another method that better corresponds to the listening requirements of home theater. Front channels fire directly into the room, side and rear channels fire into diffusers to create that non localized sound field that more closely resembles real acoustical fields.



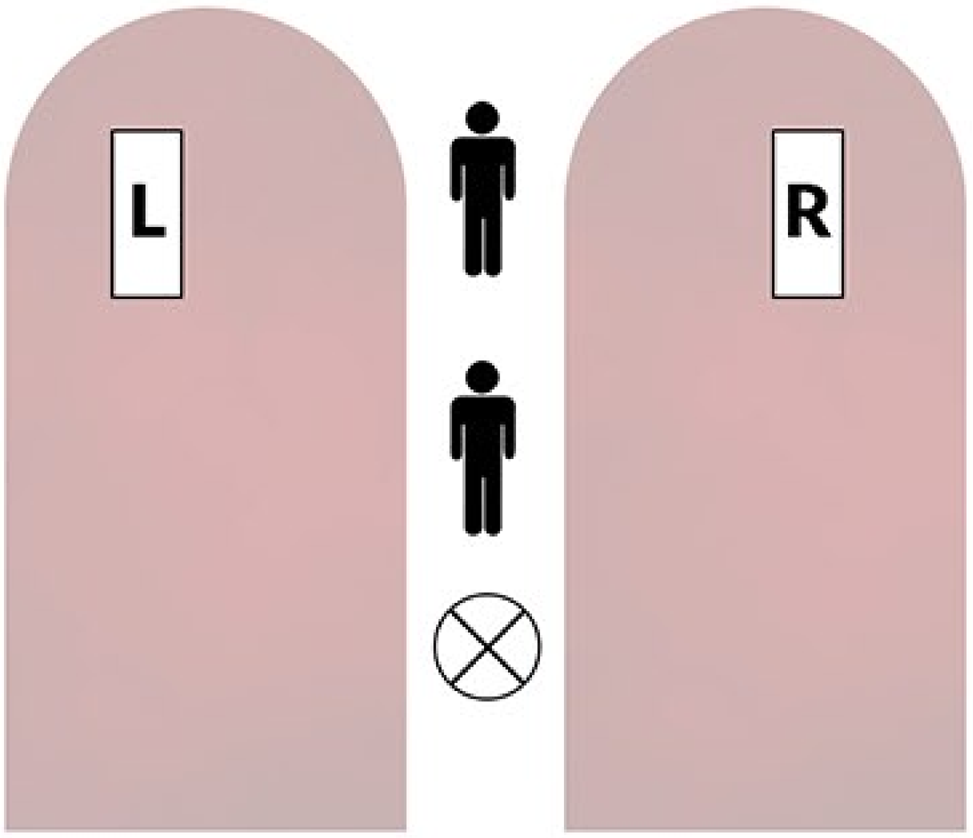
15. Subwoofer Positioning

Sub woofers are low frequency energy producing structures. Their ability to produce unwanted resonances in small rooms is well documented in the literature. The amount of low frequency devices and their relative positions within the room contributes to the amount of issues they can produce when it comes to a smooth room response. These graphics show some starting positions for multiple sources and their relative positions within today's small rooms.



16. Pressure Areas Within Our Rooms

Pressure areas within our rooms are created by our left and right channel speakers. These pressure zones can be heard by rising above the pressure areas and listening closely. Simply stand up at the listening position and rise above the direct energy from your speakers and you can hear the output of the speakers and the energy fields each channel produces. It is this understanding of reflections and pressure in the left and right channel domains that we must manage correctly to achieve the most out of our two channel systems.

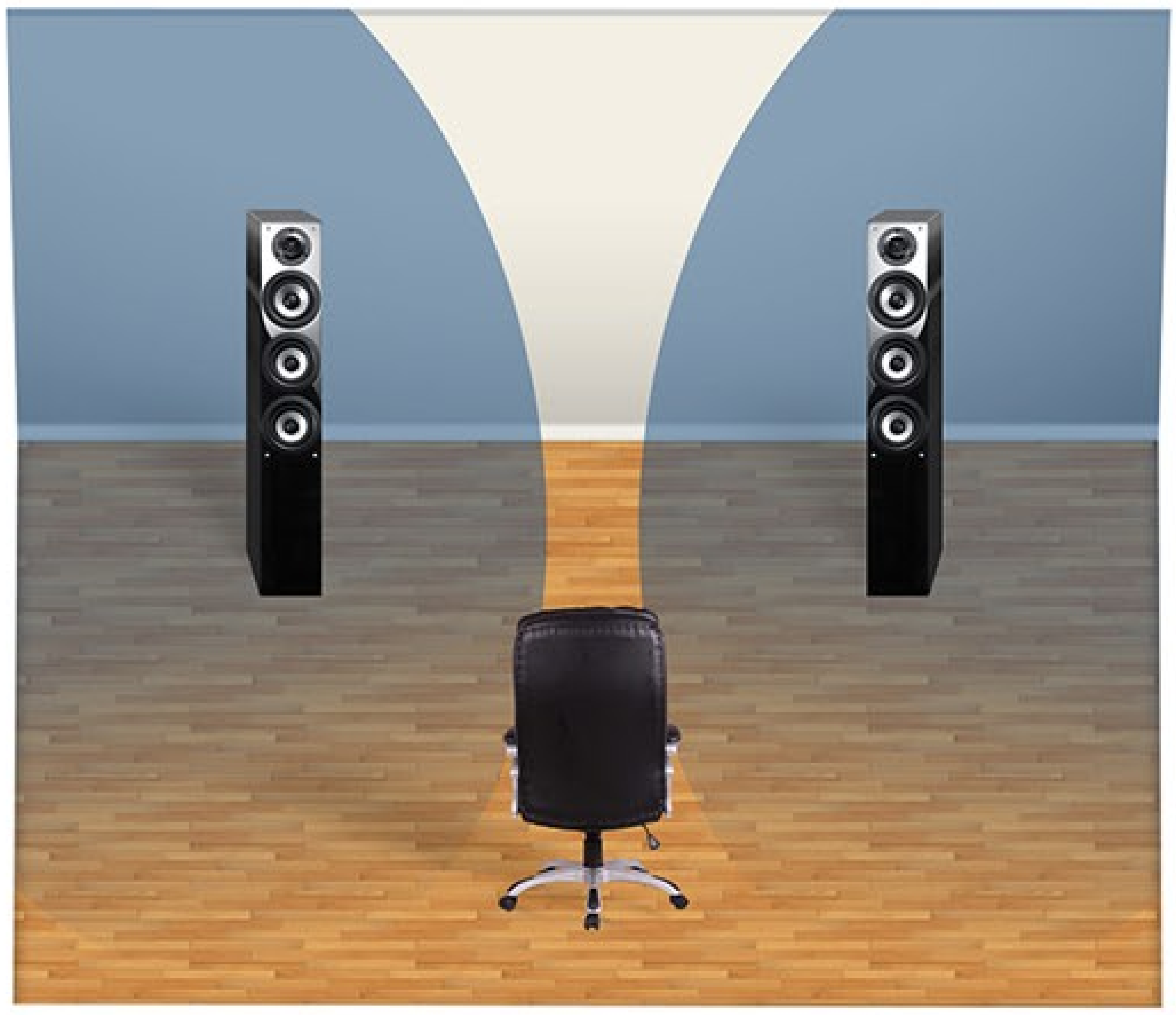


17. Speaker Sound Field

The area or sound field created by our speakers that we use to hear most of of the sound created by those speakers extends from the top of our speakers to the bottom. All you have to do to realize this is stand up and place your ears above the tweeter. You will hear the difference between the direct energy from those speakers and the reflected energy from our room boundary surfaces.

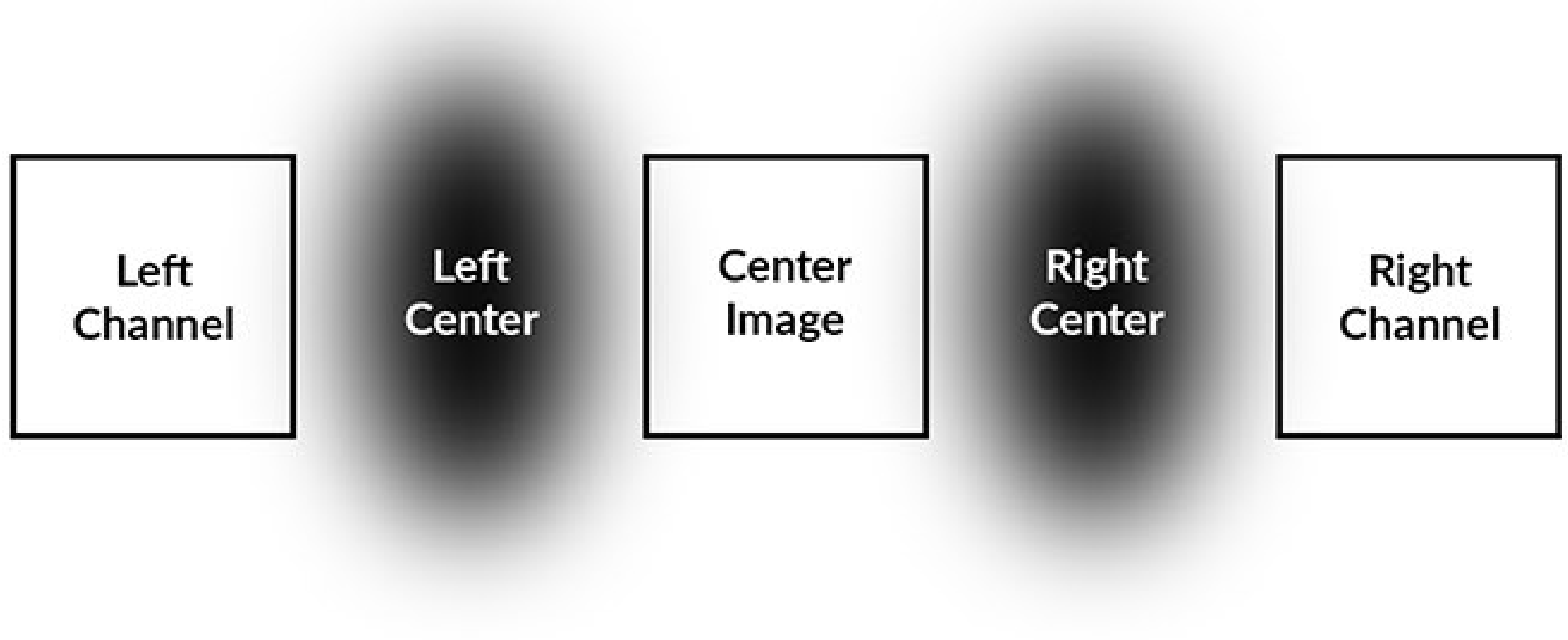
18. Horizontal & Vertical Sound Fields

Sound fields are created by our speakers in both vertical and horizontal domains. We must manage these domains accurately, if we are to maximize the performance of our two and for that matter, multi channel channel systems. The understanding of these acoustic fields is critical to our sound stage presentation. When we realize the extent and focus of these fields, we can then begin to realize their limitations and then maximize performance and minimize limitations.



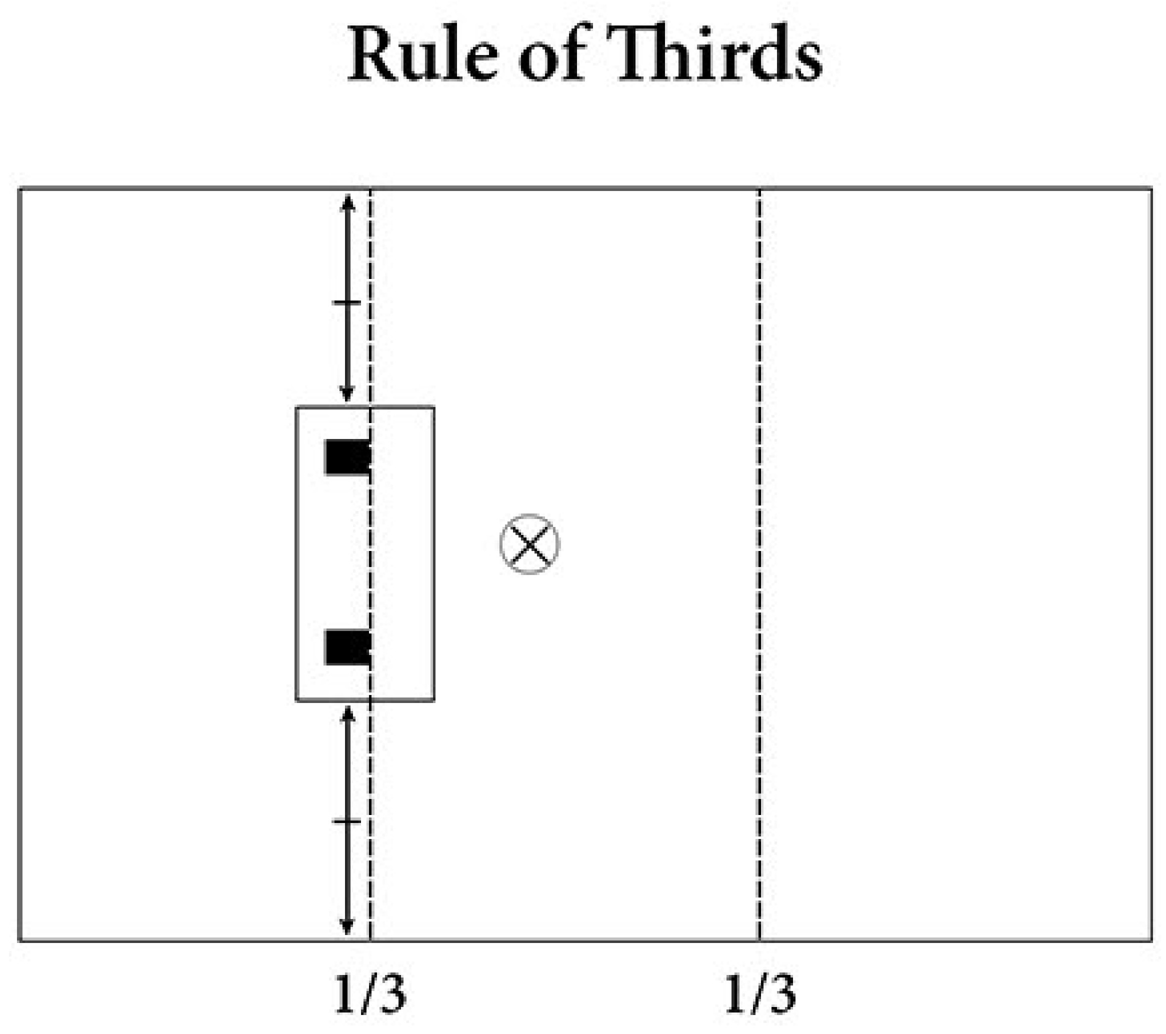
19. Center Image in Two Channel Audio

In two channel audio, we have a right and a left channel. We try and achieve a strong center image by setting all of our distances from surface boundaries and distances from speaker to listener. On each "side" of the center image is an area that we can sometimes find a hole in the sound stage. It depends on the materials played and the SPL level One method to fill in this center image "side" area is to use diffusion technology on the front and rear walls.



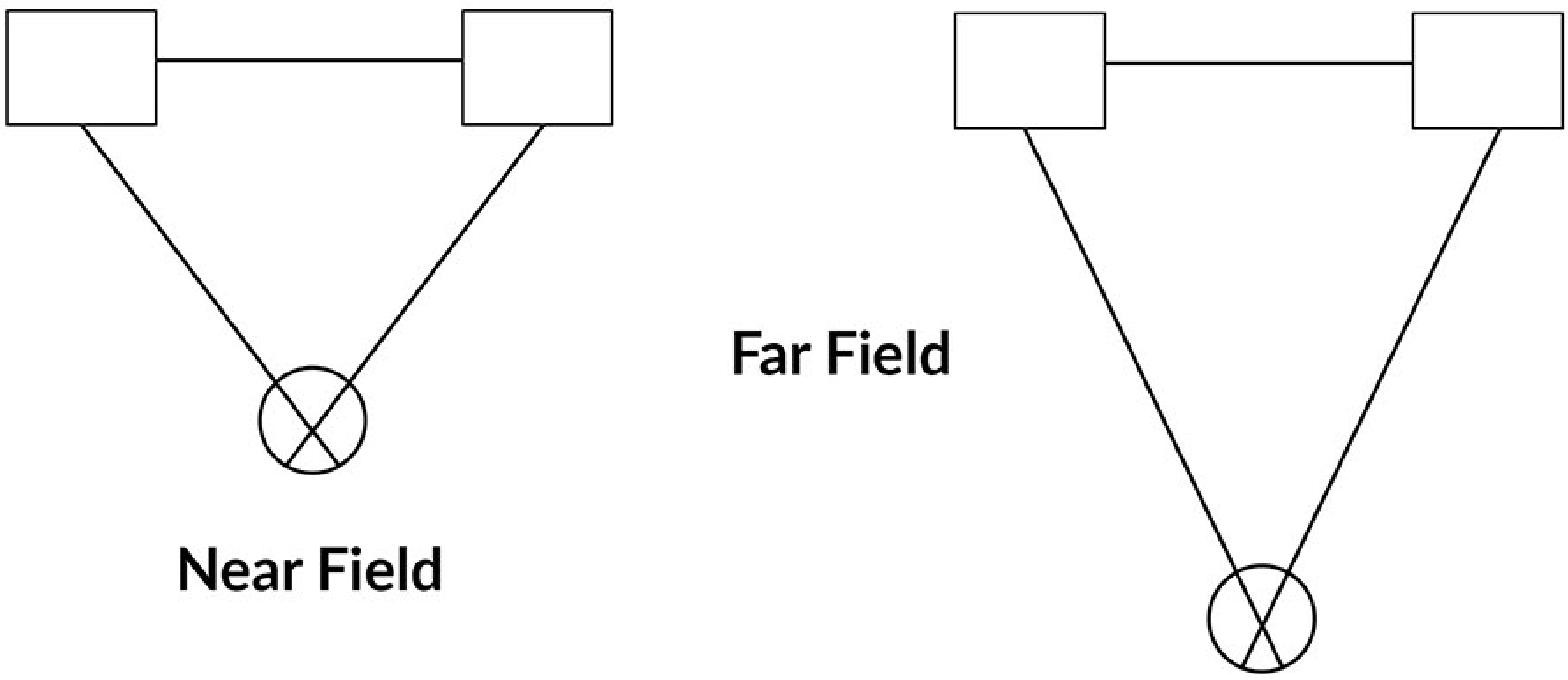
20. The Rule of Thirds

Sound travels at a constant speed through air. This speed is directly related to distance and speed and distance must be respected if we are to achieve a strong center image in our two channel presentations. The time signature of reflections from side walls must start with equal distances so we can achieve a balance between the reflected energy from our side walls and the direct energy from our loud speakers. The rule of thirds gives us a starting point to begin the tuning process.



21. Near Field & Far Field

There are two "fields" of sound in front of our speakers. There is far field and near field. Far field means that we sit and listen farther away from our speakers than near field. Far field listening allows for a wider sound stage and larger presentation. There is more room sound or reflected energy in our far field presentation. Near field means we sit closer and hear more direct or straight line sound. Near field minimizes room sound or reflections because we sit closer to the source and we hear more direct or straight line from the speaker sound.



22. Frequencies Explained

Low frequency energy is all energy below 100 Hz. This is defined by the amount, type, and surface areas required to treat energy below 100 Hz. Low frequency energy requires treatments that have larger depth requirements. Energy from 100 - 2,000 Hz. is middle frequency energy and can be treated with materials that are thinner in dimension and require less space. This rational follows with higher frequency energy above 2,000 Hz.

23. STC Charts

Noise and its transmission through structures must be understood first in order to be managed properly. Certain material combinations work better than others and its this relationship of material density that must be understood in order to successfully manage the extent of noise transmission. To stop noise, we build barriers. The composition of those barriers is frequency and amplitude dependent. Each structure with the associated densities has a STC or sound transmission class rating. The rating is based upon the structures ability to stop vibrations and minimize transmission above 125 Hz.

STC Charts

SOUND TRANSMISSION CLASS

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Noise is everyone's concern. Noise from outside our music rooms, must be kept outside where it belongs. Music (noise to some) must be kept inside of our rooms where it is created. To minimize noise, we build barriers between the noise source and ourselves, the receivers.Here are the current accepted barriers in use and the amount of noise they attenuate. Keep in mind these measurements are 30 - 40 years old but still have validity. Study for comprehension and understanding.

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

STC	Partition type
27	Single pane glass window (typical value) (Dual pane glass window range is 26-32)"STC Ratings"
33	Single layer of 1/2″ drywall on each side, wood studs, no insulation (typical interior wall)
39	Single layer of 1/2″ drywall on each side, wood studs, fiberglass insulation [2]
44	4″ Hollow CMU (Concrete Masonry Unit) [3]
45	Double layer of 1/2″ drywall on each side, wood studs, batt insulation in wall
46	Single layer of 1/2″ drywall, glued to 6″ lightweight concrete block wall, painted both sides
46	6″ Hollow CMU (Concrete Masonry Unit) [3]
48	8″ Hollow CMU (Concrete Masonry Unit) [3]
50	10″ Hollow CMU (Concrete Masonry Unit) [3]
52	8″ Hollow CMU (Concrete Masonry Unit) with 2″ Z-Bars and 1/2″ Drywall on each side [4]
54	Single layer of 1/2″ drywall, glued to 8″ dense concrete block wall, painted both sides
54	8″ Hollow CMU (Concrete Masonry Unit) with 1 1/2″ Wood Furring, 1 1/2″ Fiberglass Insulation and 1/2″ Drywall on each side [4]
55	Double layer of 1/2″ drywall on each side, on staggered wood stud wall, batt insulation in wall
59	Double layer of 1/2″ drywall on each side, on wood stud wall, resilient channels on one side, batt insulation
63	Double layer of 1/2″ drywall on each side, on double wood/metal stud walls (spaced 1″ apart), double batt insulation
64	8″ Hollow CMU (Concrete Masonry Unit) with 3″ Steel Studs, Fiberglass Insulation and 1/2″ Drywall on each side [4]
72	8″ concrete block wall, painted, with 1/2″ drywall on independent steel stud walls, each side, insulation in cavities

STC partition ratings taken from: "Noise Control in Buildings: A Practical Guide for Architects and Engineers"; Cyril M. Harris, 199

24. The 3D Sound Fields in our Rooms

There are three dimensions or fields of sound within our rooms. There is front to rear sound, ceiling to floor sound, and side wall to side wall sound. All of these three areas require treatment types, amounts, and positions to manage the energy that occurs between these boundary surfaces. Floor to ceiling energy requirements are usually the greatest because this is the shortest dimension of all three in most small rooms. Low frequency absorption is a must have in this area. Side wall to side wall issues are next for treatment and side wall reflections and time signature are critical in the width of our sound stage presentation. Absorption is the chosen technology for side walls. Front wall to rear wall energy requirements are the longest in dimension but require a choice between absorption and diffusion technologies.