Acoustic Realities of Small to Medium-Sized Rooms

Investigating the Acoustic Challenges and Solutions for the Average Room

Acoustics and Psychoacoustics, MUSC 7664X
Brooklyn College, Sonic Arts MFA
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Abstract: One of the most daunting challenges for today's "bedroom" producers is poor monitoring conditions. With the gradual emergence of more affordable pro-audio equipment, many producer have opted to create music primarily in their home-studios rather than pay high hourly rates for professional studios. Much of the same software and to a certain degree, hardware, is now used both by home based artists as well as studio based artist, thus narrowing the gap in what is possible between their respective creations. However, the ability to monitor accurately is often still a huge challenge for home-based artists. Proper studio treatment requires a keen understanding of acoustics and copious amounts of absorption and diffusion surfaces to attain desirable monitoring results. In many cases, acousticians are consulted before the physical walls of the studio are even built in order to create the most effective plan for an ideal monitoring situation. Besides the near impossibility of building a room from scratch, the notion of hiring a professional acoustician and diving down the rabbit-hole of purchasing and/or building acoustic treatment is a daunting prospect for many bedroom producers. This presentation covers some of the more well-known, practical and affordable approaches for optimizing one's listening environment.

Overview

1. The importance of proper monitoring conditions.
2. The acoustics of small/mid-sized rooms.
3. Solutions for an optimized listening environment.
4. Goals + my own adventure.

1. The importance of proper monitoring conditions.

“When you consider that a typical untreated domestic acoustic environment will, in my experience render roughly two thirds of the money you spent on your speakers wasted, there’s simply no excuse for inaction if you’re serious about your craft.”

-“Mixing Secrets for the Small Studio” p. 17, Mike Senior

AES 2017

Mike Senior

Mind blown

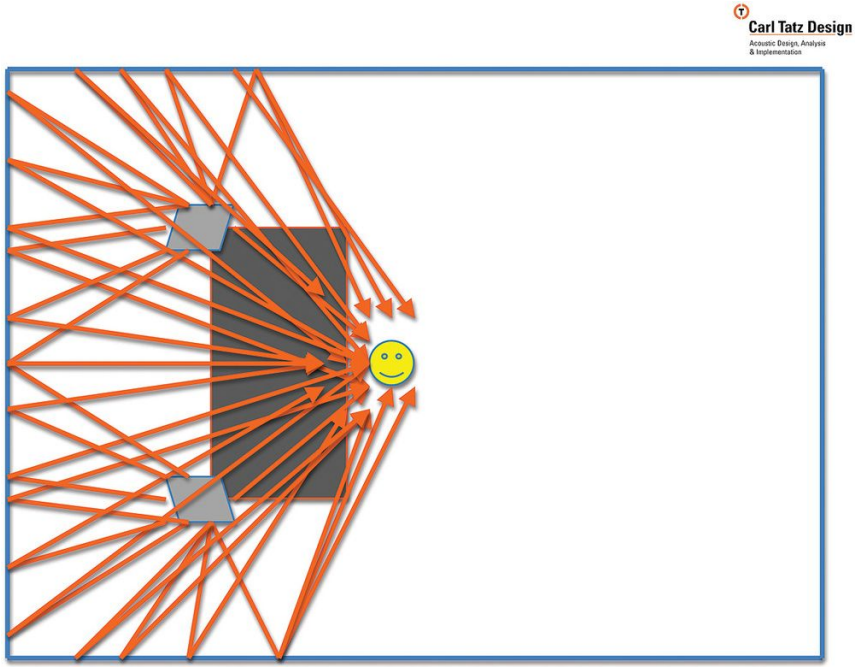
2. The acoustics of small/mid-sized rooms.

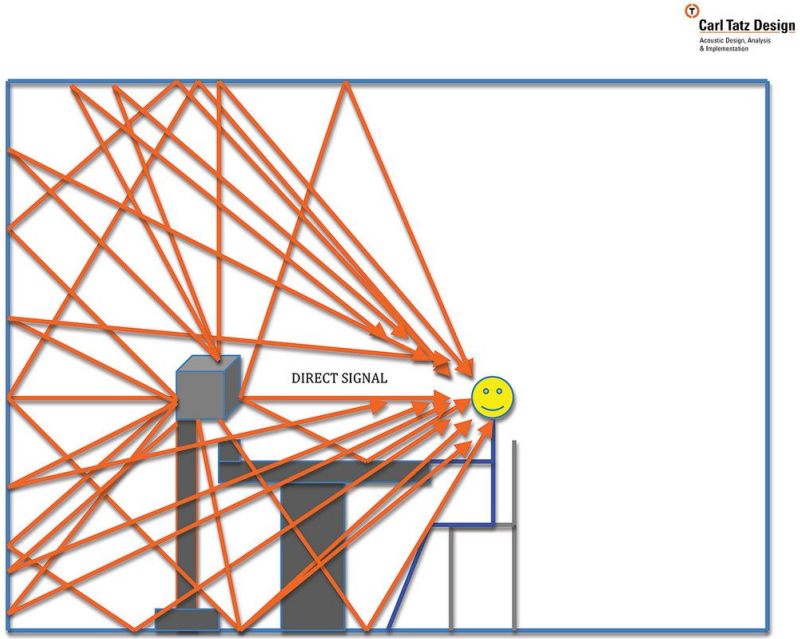
What do we hear when sound is generated by speakers?

1) direct energy
2) reflected energy

Reflected energy:
A) reflections (early and late)
B) standing waves (room resonances and flutter)

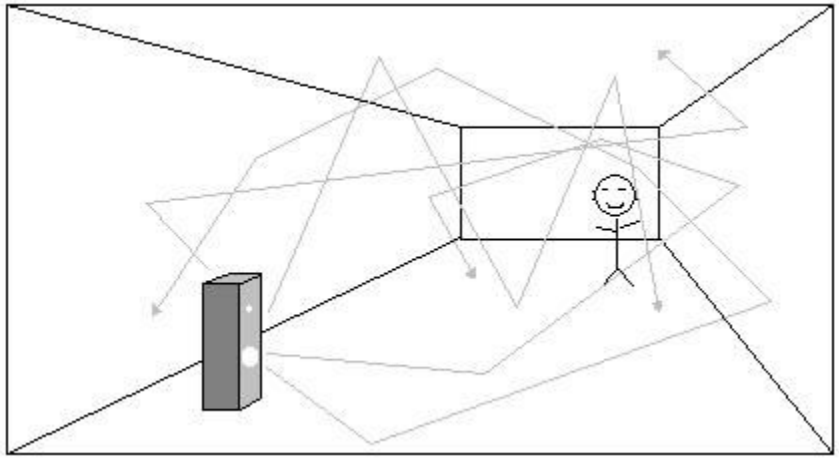
Early reflections:





Images: https://www.soundonsound.com/techniques/elephant-control-room

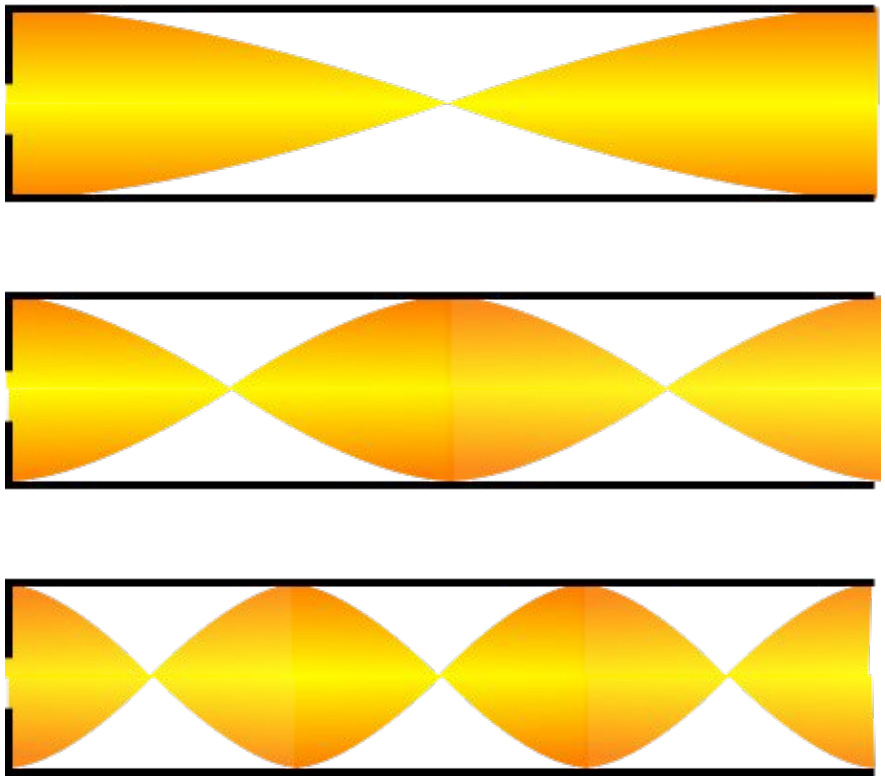
Late reflections:



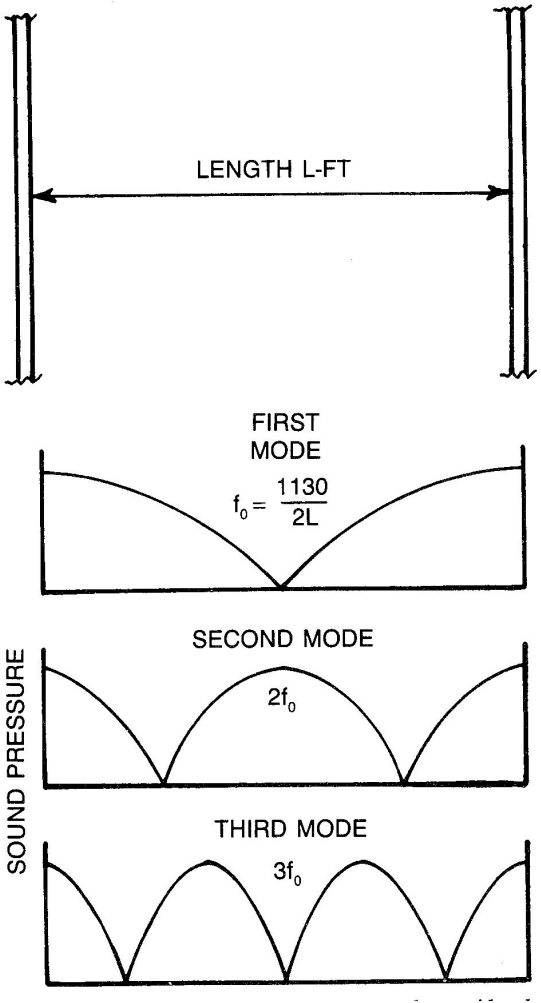
http://www.bobgolds.com/RT60/rt60.htm

Room resonances:

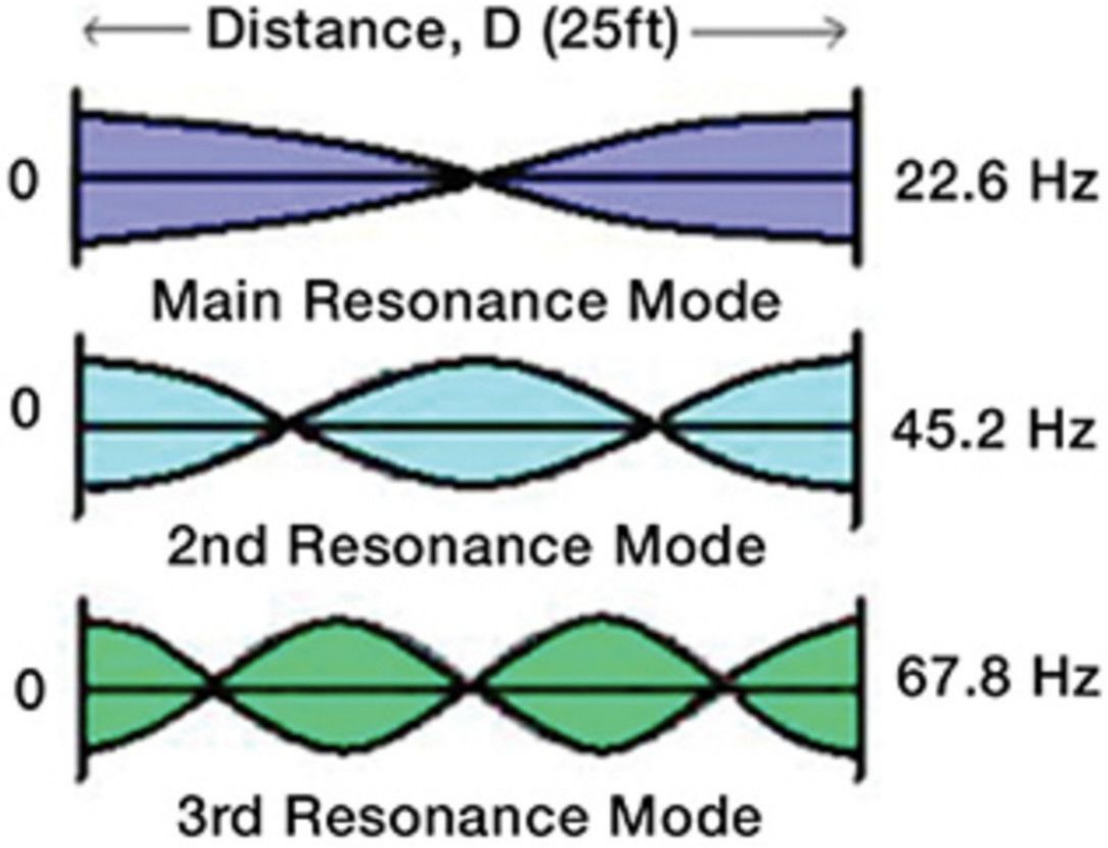
(like a guitar string)



http://www.ecomusee-bresse71.fr/uploads/media/Actes_JE_2016.pdf

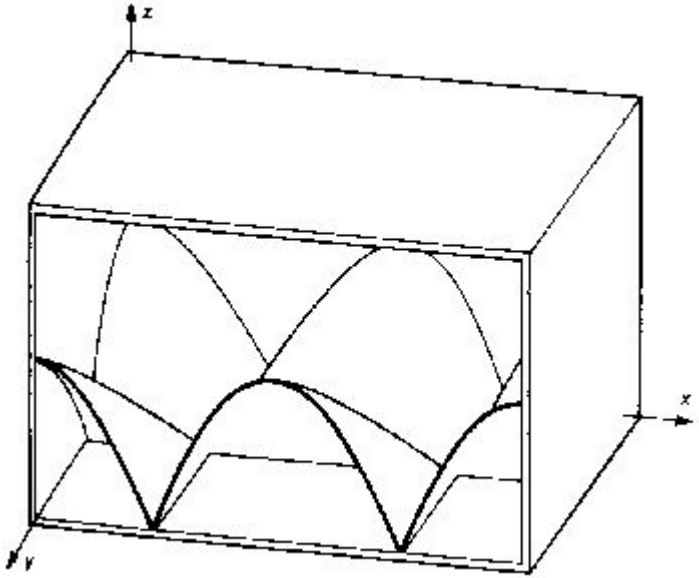


https://www.audioholics.com/room-acoustics/listening-room-acoustics-1

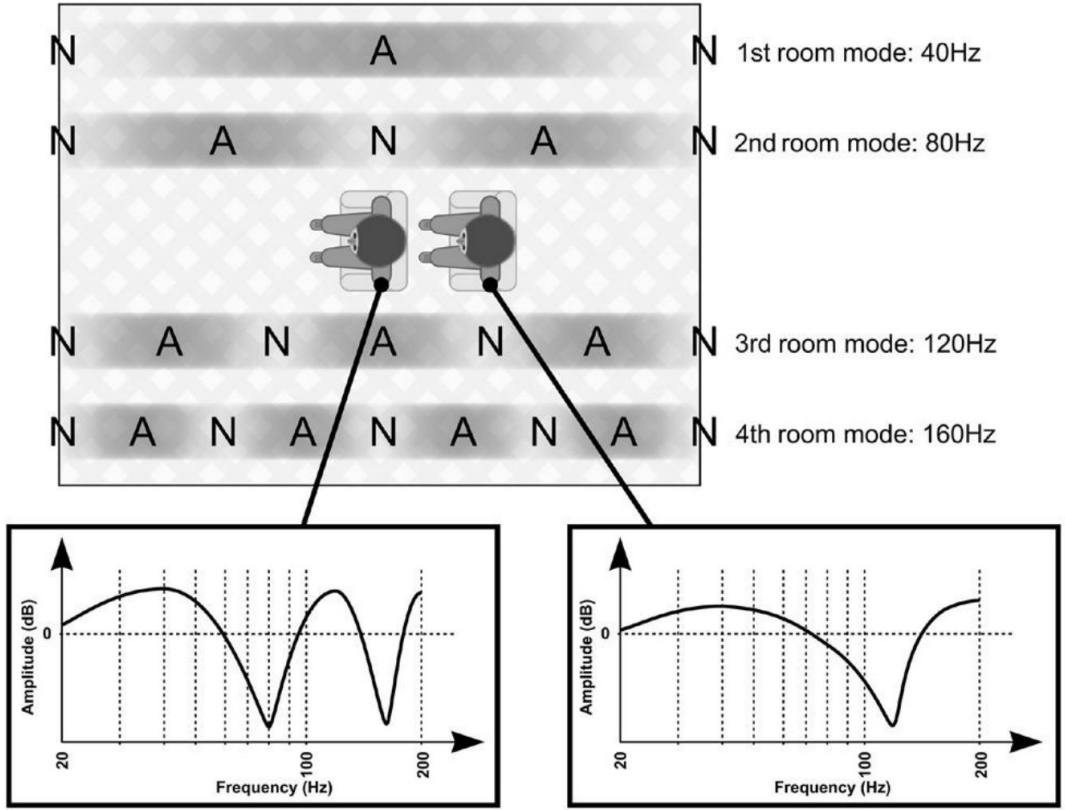


https://en.wikibooks.org/wiki/Engineering_Acoustics/Basic_Room_Acoustic_Treatments

3D:

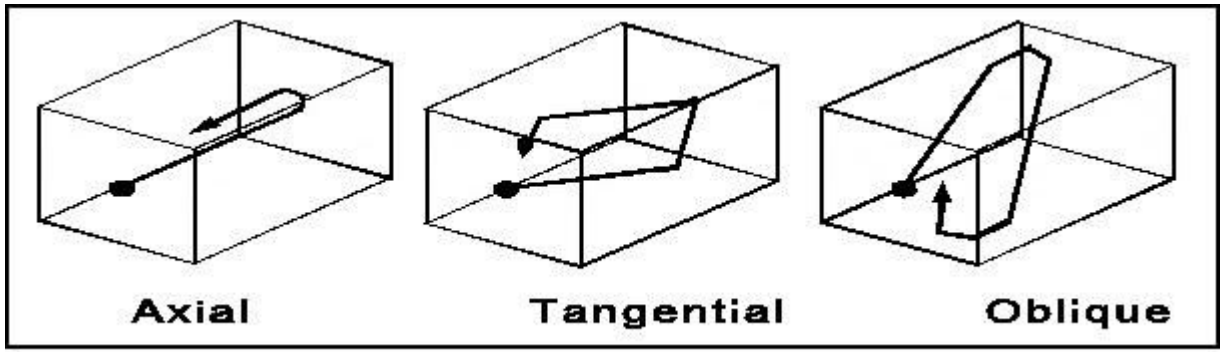


http://www.mcsquared.com/metricmodes.htm



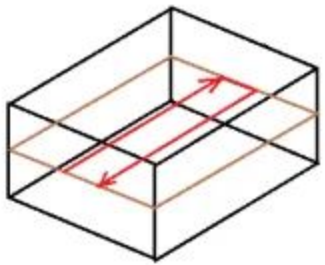
Mixing Secrets for the Small Studio, Mike Senior. P. 22

These resonances occur in 3 ways:

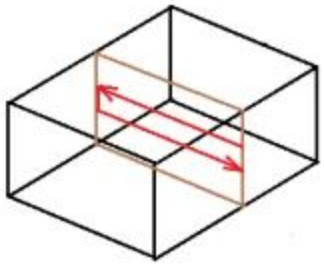


http://www.roommodes.com/

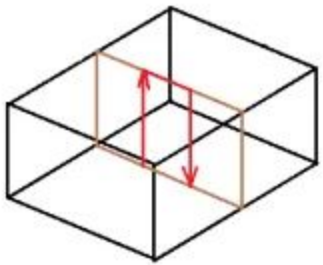
And each occurs over various dimensions:



Length Mode



Width Mode

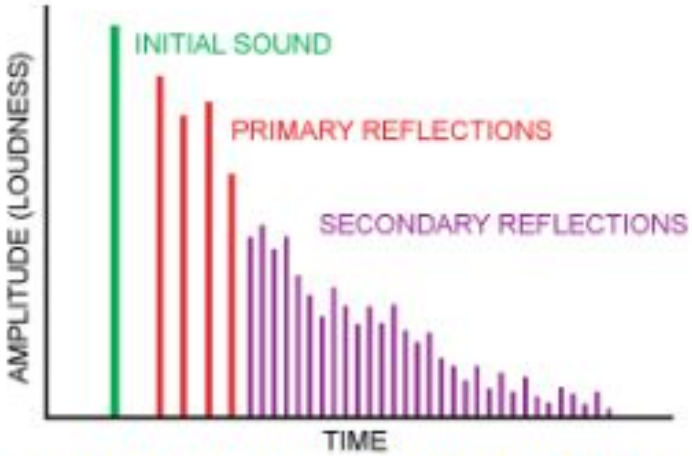


Height Mode

https://fromvinyltoplastic.com/acoustics-101-sound-basics/

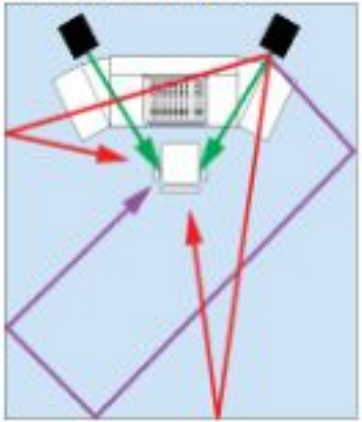
In summary:

Common Room Problems



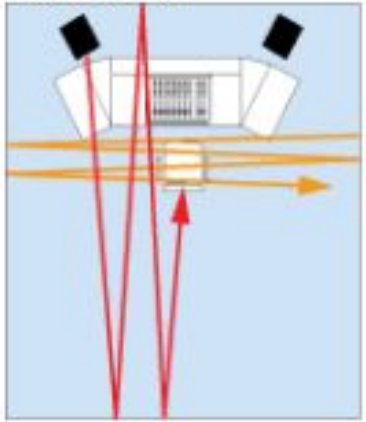
It starts with the initial sound, then strong first order reflections. Then the reverberant field is created over time as sound bounces around the room.

Primary Reflections



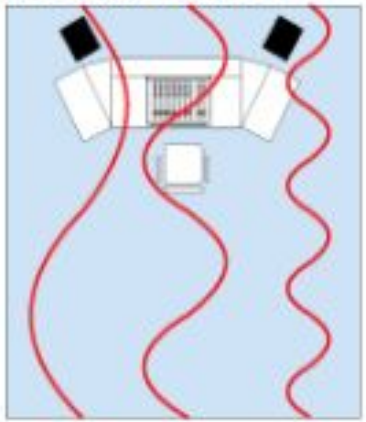
- Direct Sound
- Primary Reflections
- Secondary Reflections

Parallel Walls



- Front to Back Flutter
- Side to Side Flutter

Resonance & Modes



- Resonance Frequencies

These phenomena cause problems in monitoring:

Early + Late Reflections:
-comb filtering

Standing waves:
-flutter echoes (noticeable mostly with transients, but for all sound)

Resonances:
-deep boosts and cuts along nodal and antinodal points (up to 15 or 20 dB between a peak or a trough)
-boundary effect (anti-nodes at walls & corners) = 3dB boost at wall, 6dB boost at corner

All:
-time domain smearing

3. Solutions for an optimized listening environment

A) Good room choice
B) Optimal listening position
C) Proper speaker placement
D) Eliminating direction reflections from angles of hard surfaces
E) Absorption
F) Diffusion
G) Software based calibration

A) Room Choice

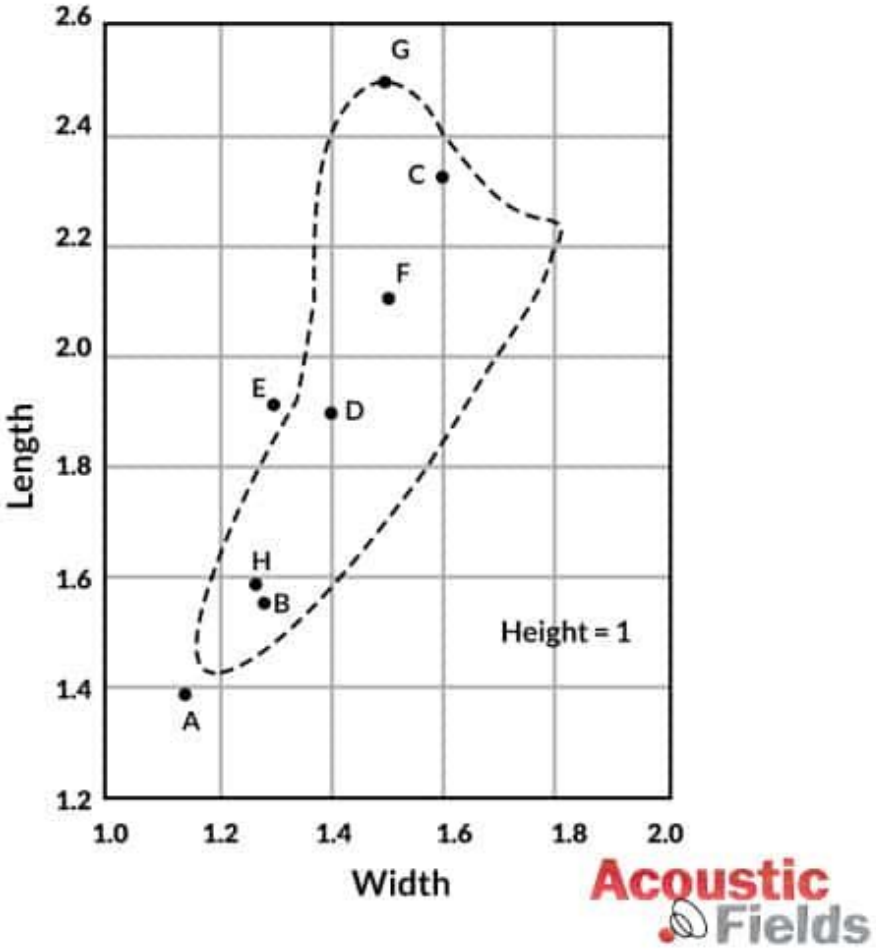
1) Avoid small rooms - their resonances interfere most with the frequencies we want to work with

W	H	L	cu.ft.	m^3	
9' | 2.43m	11' | 3.35m	10' | 3.04m	990	24.75	[RED] Find a larger room. Extensive low frequency treatment required
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	[YELLOW] Treatable/large areas of coverage. Good low, middle, and high end.
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	[GREEN] Minimal EQ required. Strong low, middle, and high end.
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	

https://www.acousticfields.com/small-and-large-room-acoustics/

Bonello chart: another way to visualize ideal room sizes

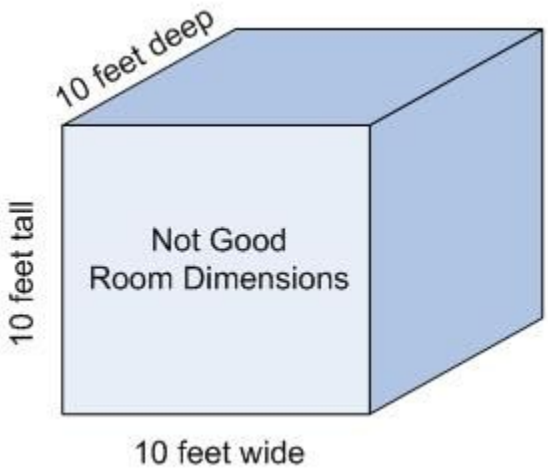
Bonello: Argentine acoustician who found th the best rooms contain an increasing # of modal resonances for each higher ⅓ octave band.

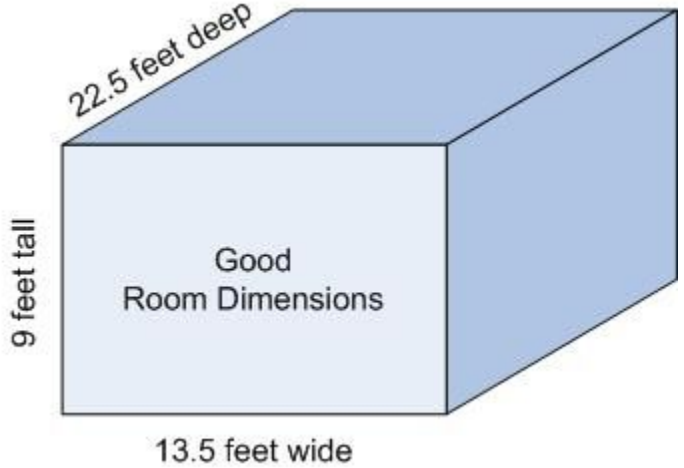


https://www.acousticfields.com/ideal-room-size-ratios-apply-bonello-graph/

A) Room Choice

2) Avoid rooms with more than 1 pair of parallel surfaces that are the same distance apart
-these rooms produce “modal coincidences” - modes tend to “gang up” and exaggerate each other's effects

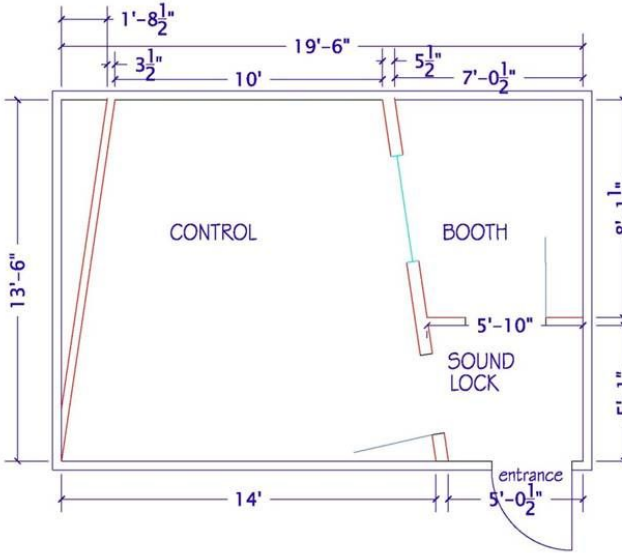




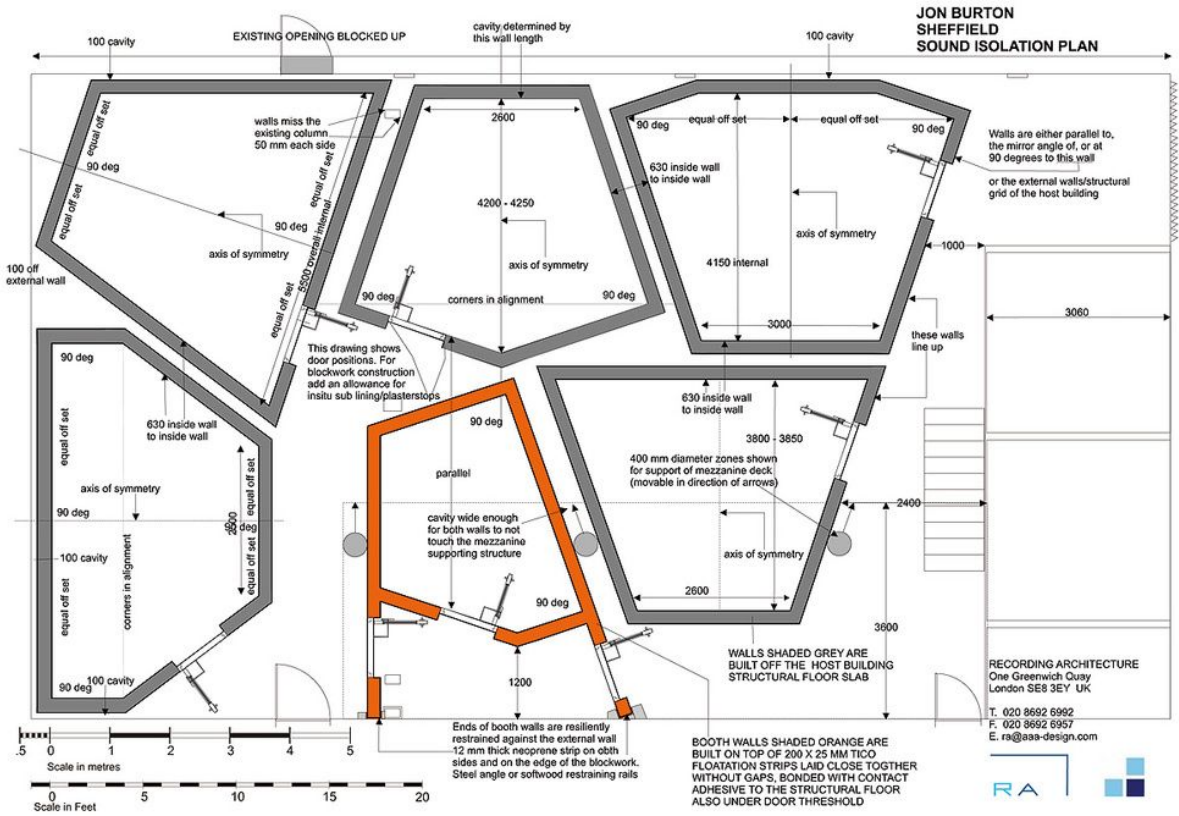
http://thehometheaterbook.com/home-theater-room-dimensions/

A) Room Choice

3) Rooms with non-parallel walls are optimal. However, they're harder to find and often especially designed for monitoring.



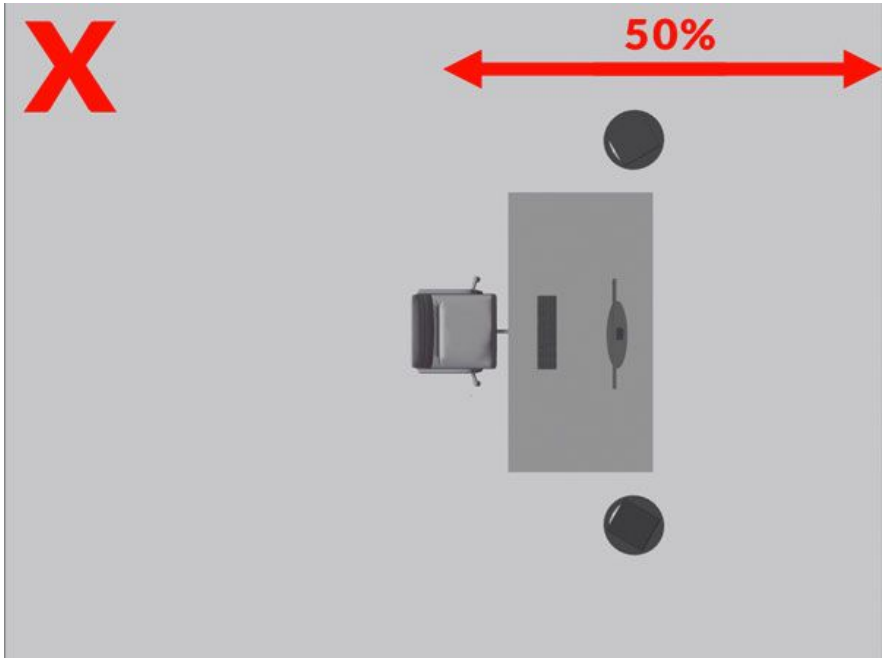
http://www.soundcontrolroom.com/wp-content/media/Room-with-Angled-Walls.jpg

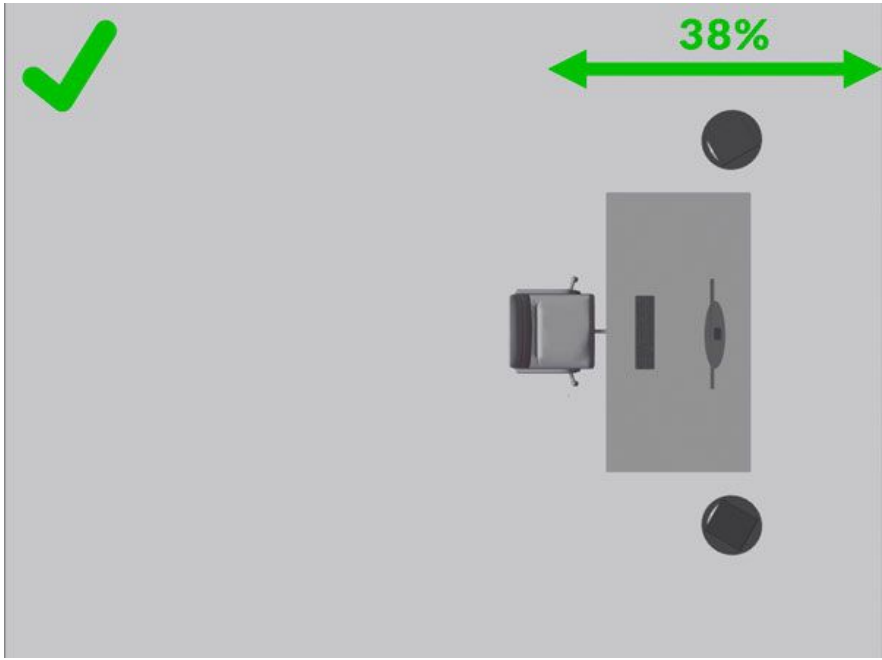


http://onysid.co/how-to-build-a-home-studio/

B) Listening position

1) As much as possible, the listening position should be in a point of neutral pressure. 38% Rule:

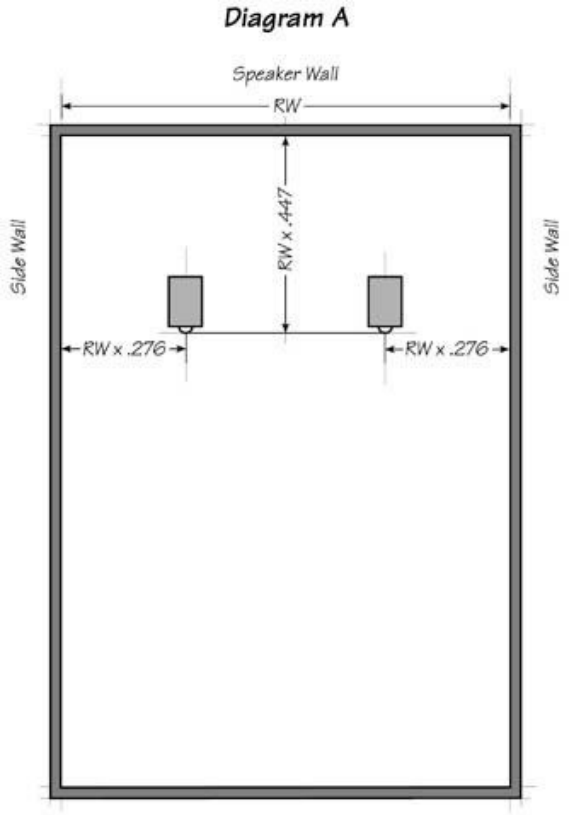




https://www.blackghostaudio.com/blog/how-to-improve-room-acoustics-without-acoustic-treatment

B) Listening position

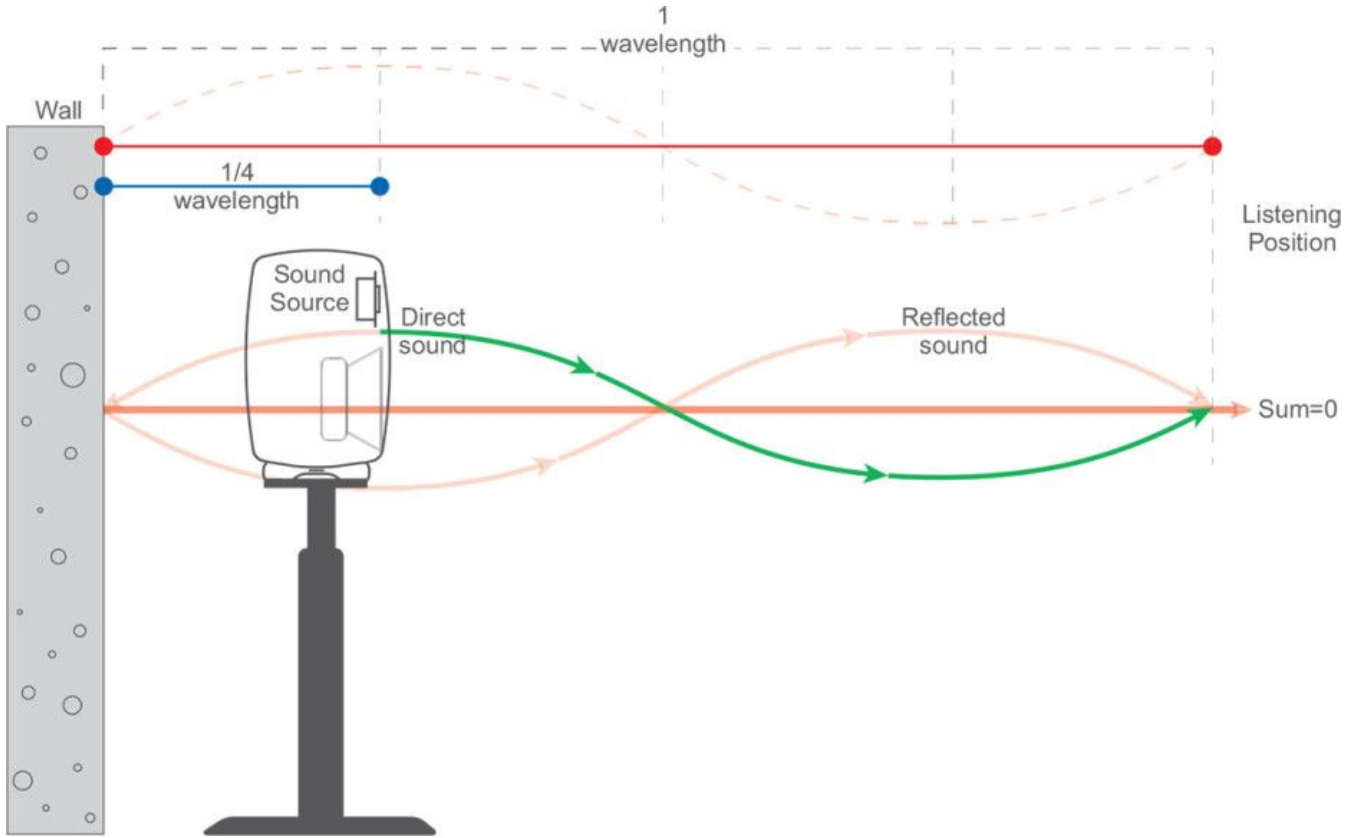
1) Another take on this concept:



http://www.cardas.com/room_setup_rectangular_room.php

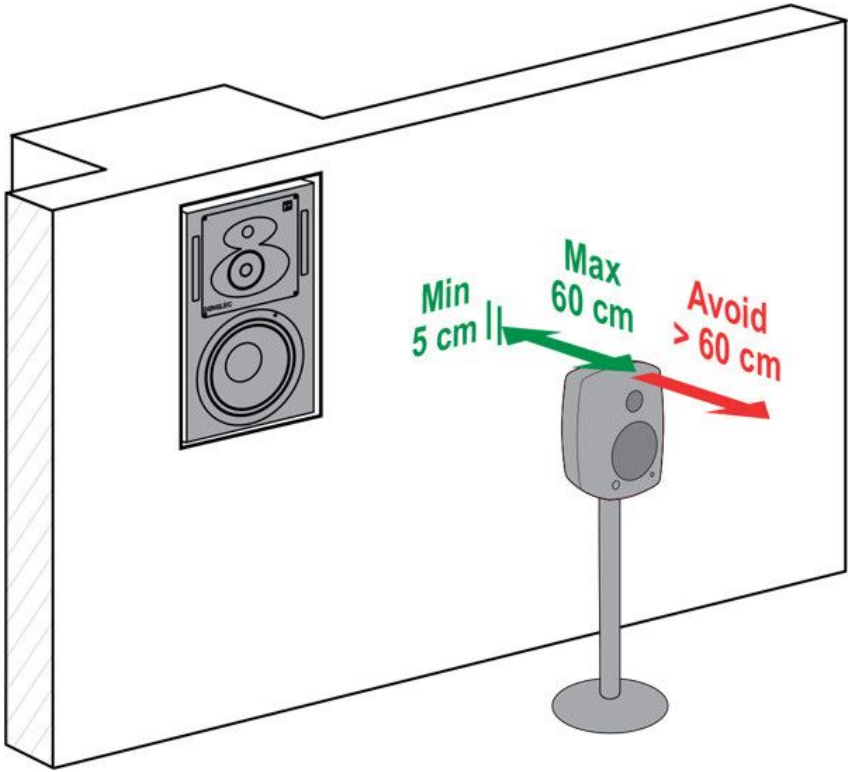
C) Speaker Placement

1) Place speakers close to wall to avoid low frequency comb filtering

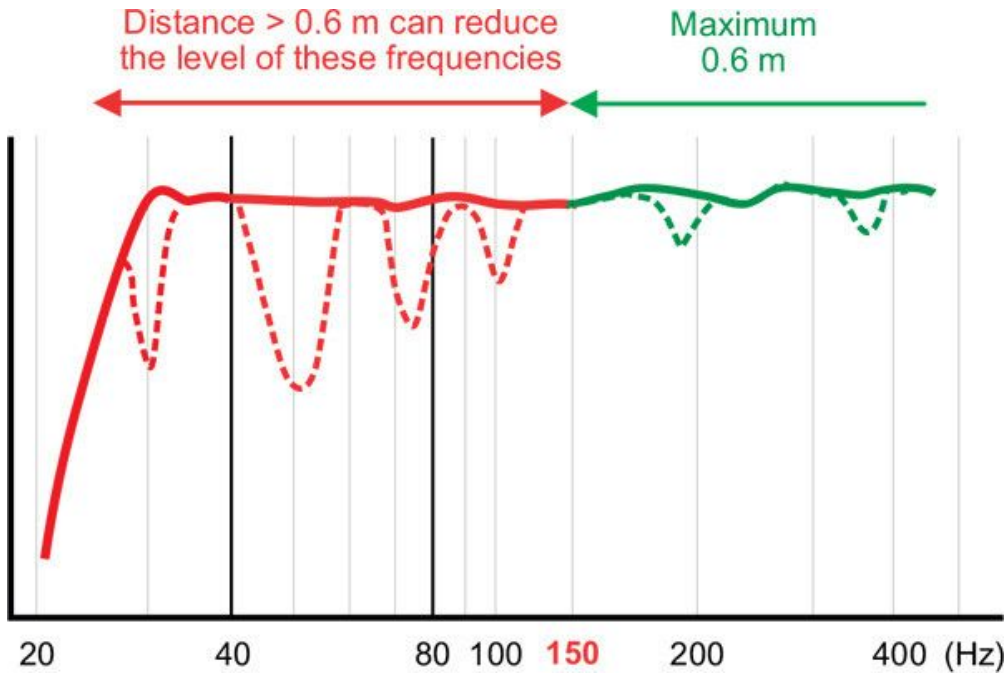


https://www.genelec.com/monitor-placement

C) Speaker Placement

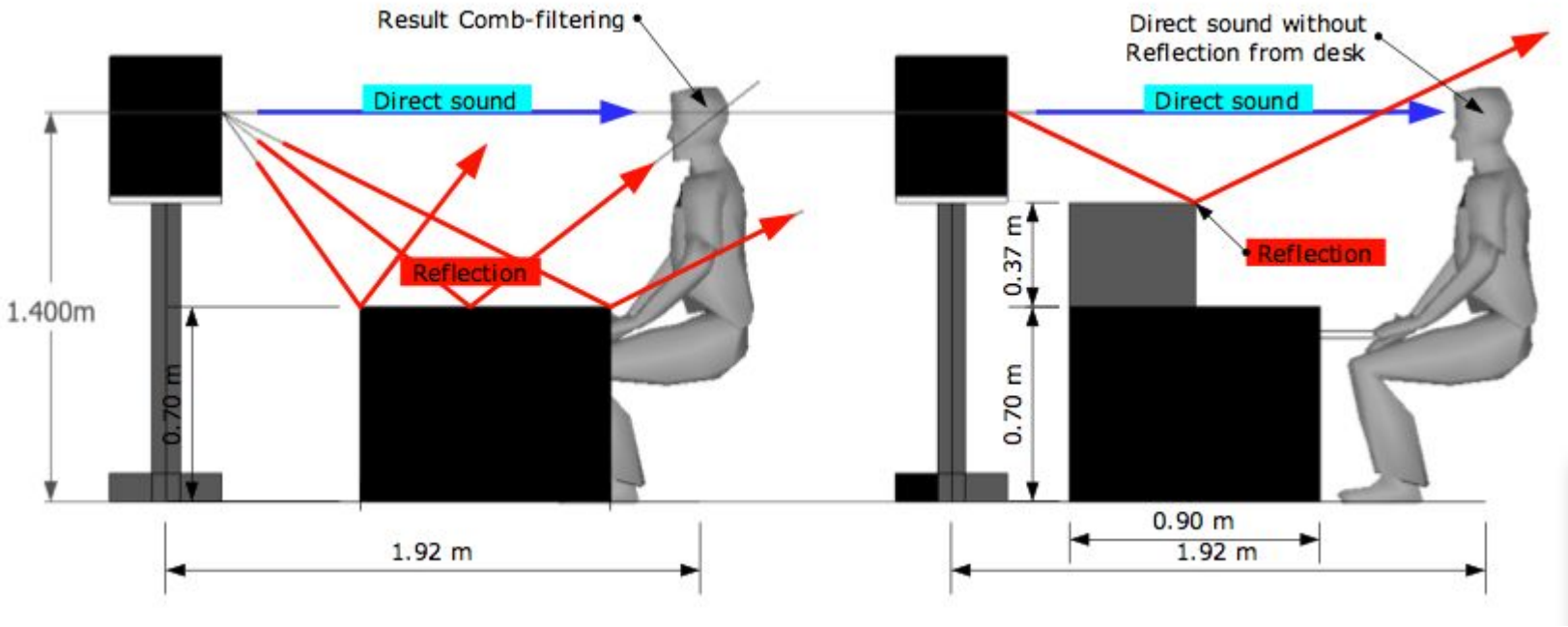


Comb filtering:

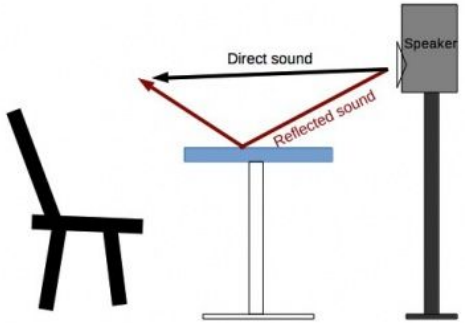


https://www.genelec.com/monitor-placement

D) Eliminating direction reflections from hard surfaces

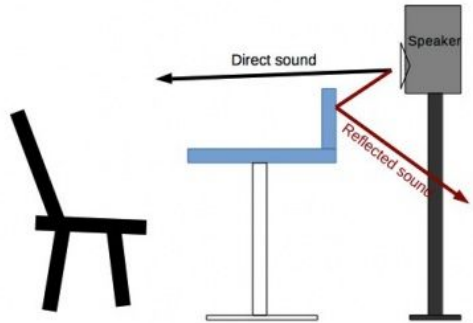


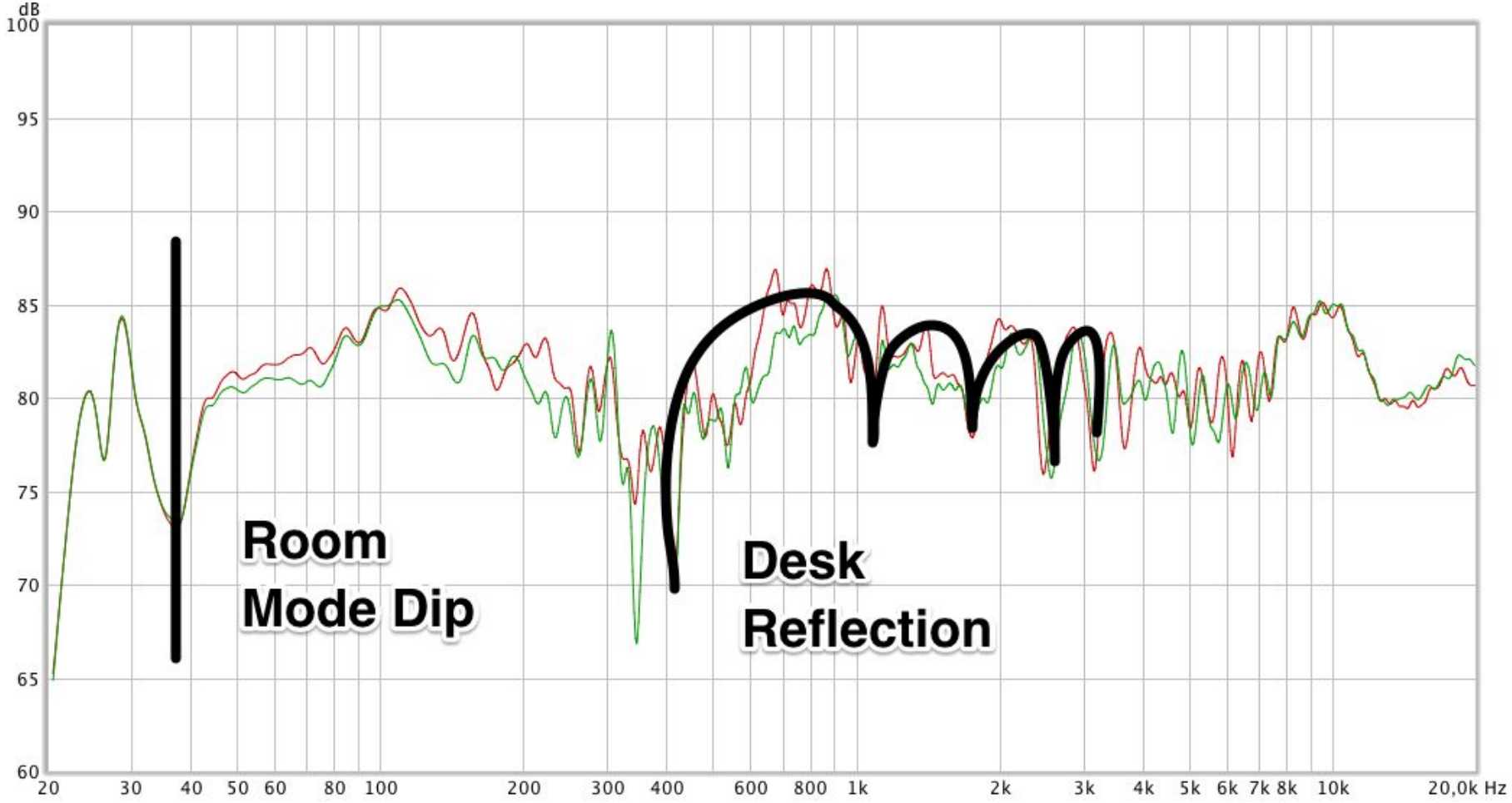
Typical flat desk surface

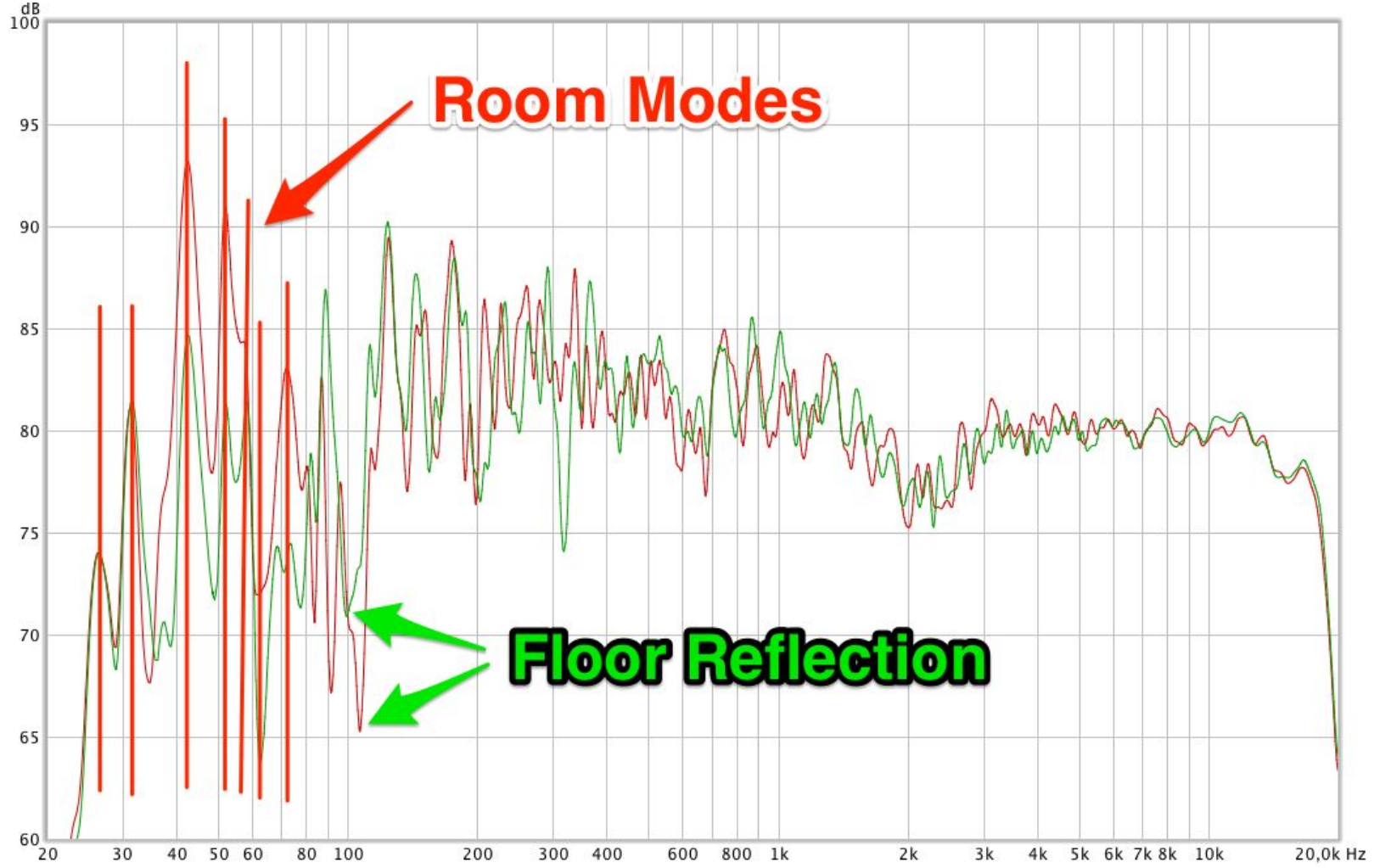


Speaker

Flat desk w/ acoustic wall

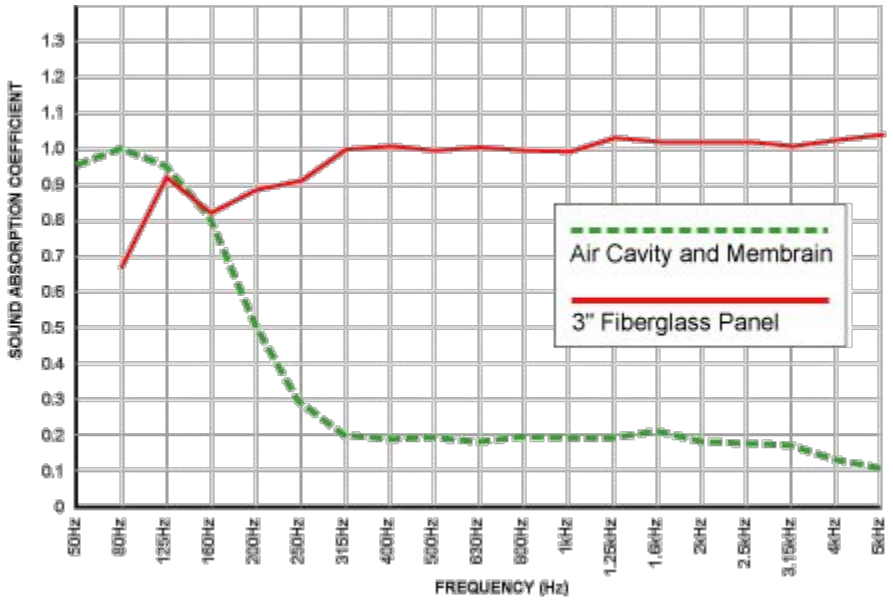



dB
100
95
90
85
80
75
70
65
60
20
30
40
50
60
80
100
200
300
400
600
800
1k
2k
3k
4k
5k
6k
7k
8k
10k
20,0k Hz
Room
Mode Dip
Desk
Reflection

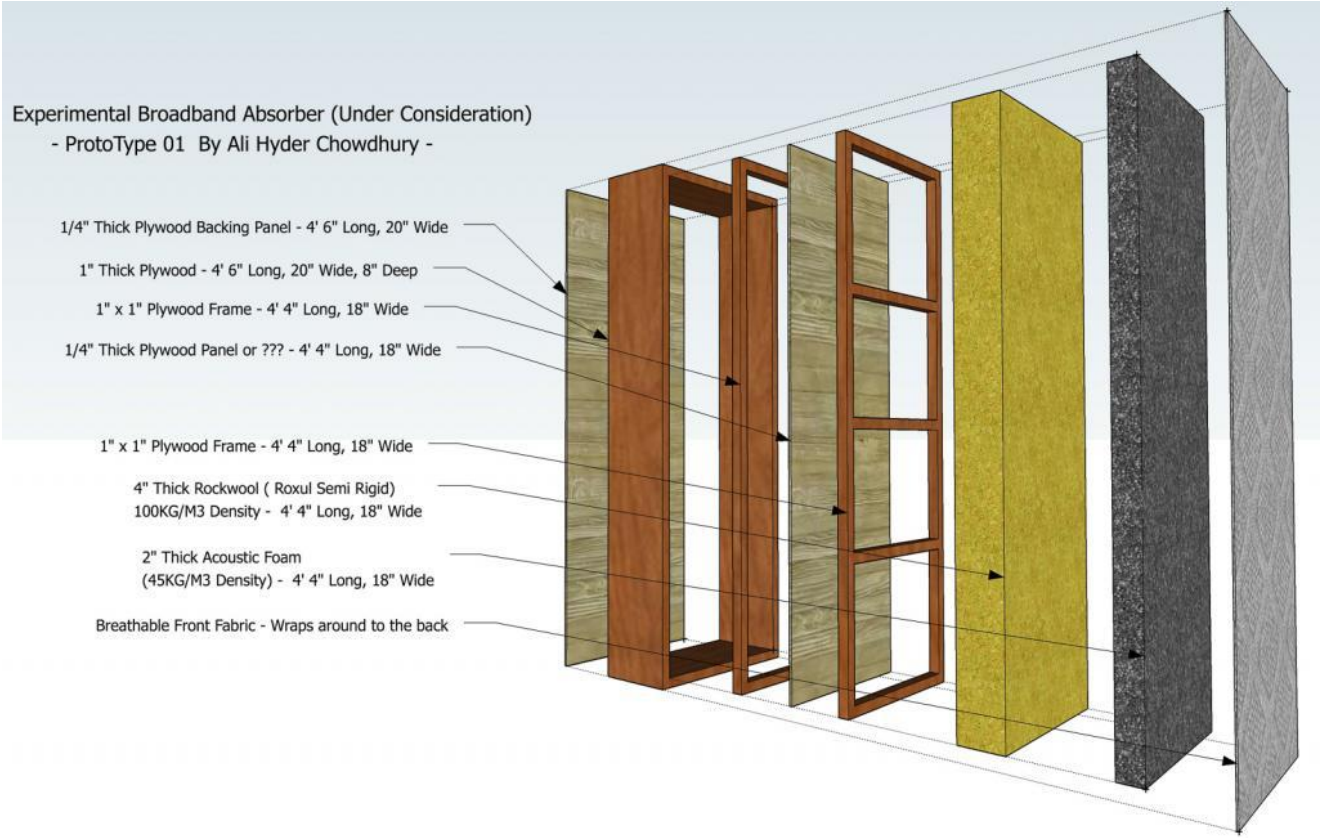

dB
100
95
90
85
80
75
70
65
60
Room Modes
Floor Reflection
20
30
40
50
60
80
100
200
300
400
600
800
1k
2k
3k
4k
5k
6k
7k
8k
10k
20,0k Hz

E) Absorption

-Broadband vs. Membrane
-Broadband: for treating a wide range of frequencies
-Membrane: tuned to a specific frequency range



Broadband



https://www.gearslutz.com/board/bass-traps-acoustic-panels-foam-etc/866452-experimental-broadband-absorber-making.html

Broadband

ACOUSTICAL PERFORMANCE			LOW	MID			HIGH		
TYPE	DENSITY	THICKNESS	125	250	500	1000	2000	4000	NRC
FIBERGLASS	3#	1"	0.11	0.28	0.68	0.90	0.93	0.96	0.70
FIBERGLASS	3#	2"	0.17	0.86	1.14	1.07	1.02	0.98	1.00
FIBERGLASS	3#	4"	0.95	1.11	1.17	1.07	1.07	1.06	1.10
FIBERGLASS	6#	2"	0.19	0.78	1.16	1.13	1.06	1.06	1.05
MINERAL WOOL	8#	2"	0.39	0.84	1.08	1.01	1.02	1.01	1.00
MINERAL WOOL	8#	3"	0.68	0.92	1.08	1.03	1.03	1.03	1.10
MINERAL WOOL	4#	4"	1.06	1.07	1.12	1.04	1.07	1.08	1.10

POOR ABSORPTION
GOOD ABSORPTION
GREAT ABSORPTION

Membrane

4kg/m2 MLV,
tuned to 80 Hz
and 100 Hz

Tuning a membrane absorber:

f = 170/sqrt(m x d)

m=mass of the membrane (lb/sqft)
d=depth of the box (inches)

http://www.acousticsciences.com/art-noxon/limp-mass-membrane-bass-traps

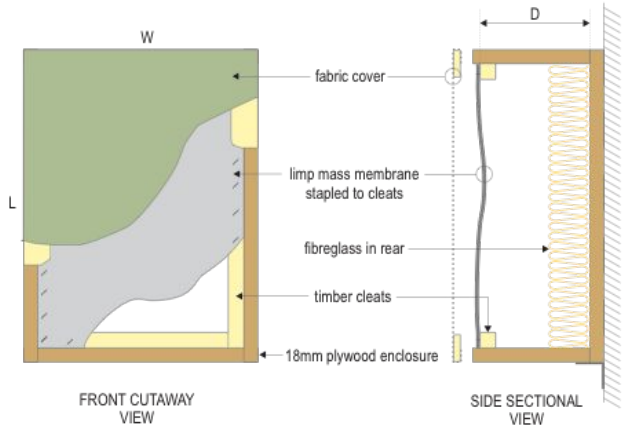
https://www.gearslutz.com/board/bass-traps-acoustic-panels-foam-etc/743040-tims-limp-mass-bass-absorbers-28.html

Membrane

buzzaudio

SIMPLE LIMP MASS BASS ABSORBER

by Tim Farrant



CALCULATING THE APPROXIMATE RESONANT FREQUENCY

$f_o = \frac{600}{\sqrt{MxD}}$ where M is surface density (mass) of membrane in kg/m^2 and D is depth of enclosure in cm

$f_o = \frac{170}{\sqrt{MxD}}$ where M is surface density (mass) of membrane in lb/ft^2 and D is depth of enclosure in inches

DESIGN NOTES

1] The limp mass membrane can be any flexible non-porous material. Barium loaded neoprene sheet and similar heavy flexible sheeting used for noise barriers is ideal. The higher the mass of the material means very low frequency absorbers can be made with relatively shallow enclosures. For example, a membrane with mass of 5kg/m across a box 30cm deep will resonate at approx 50Hz.

2] The box L x W is not critical but should be kept small compared to the wave length of the resonant frequency. The limp mass bass absorber is not effective beyond 300Hz for this reason. Typical L x W would be 60 x 40 cm for frequencies below 100Hz, and 40 x 30 cm for frequencies above 100Hz.

3] The enclosure must be airtight. The membrane should be sealed onto the cleats using a gap filling sealant. Test for airtightness by pushing the membrane in and observing it bulging out. The enclosures can be built directly onto the wall eliminating the need for a back panel but must be rigid. The fabric cover may be global to cover several enclosures.

4] Fibreglass thickness is not critical and it's presence lowers the "Q" of the absorber. For boxes with a depth greater than 20 cm, 50mm (2") building insulation can be used, for boxes less than 20cm 25mm (1") can be used. Avoid very high density fibreglass which will make the enclosure acoustically shallower than it really is.

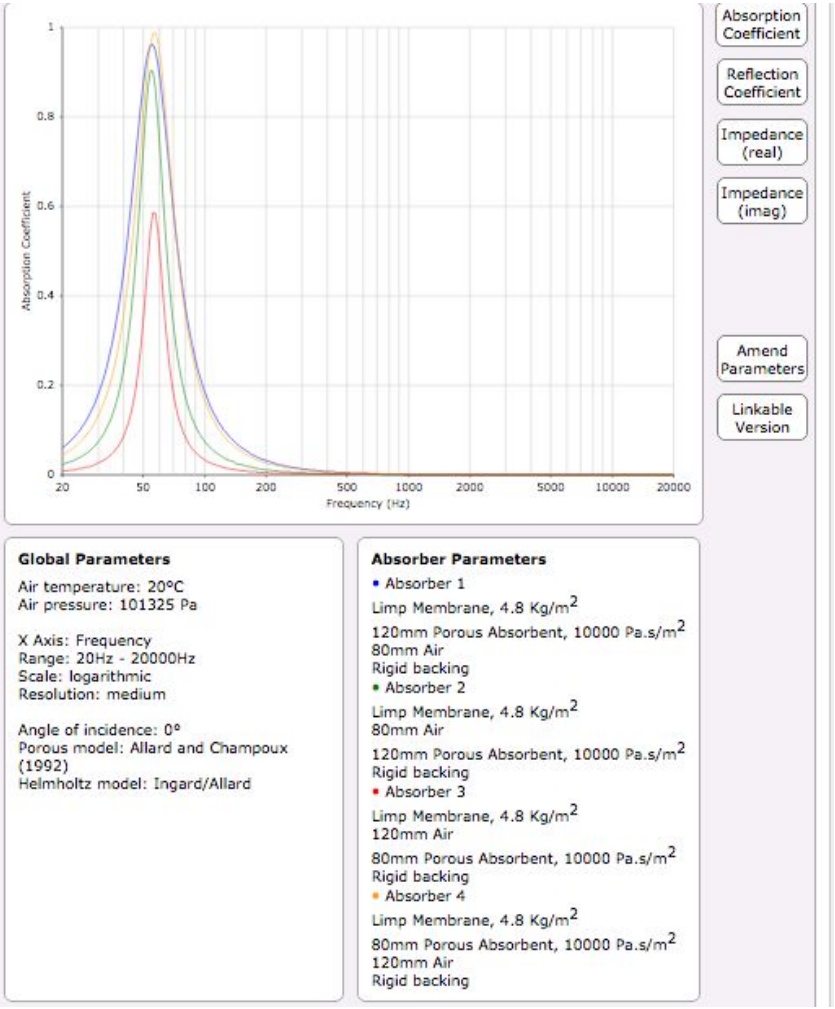
5] Mount the bass absorbers into the corners of the room. Making various depth absorbers and mounting them in an alternating pattern will increase effectiveness. Mount very low frequency absorbers at the wall-wall-ceiling corner if possible.

12/3/2019 limpmasscalc.xls

			D1
	LIMP MASS ABSORBER		
	Metric		
	Enter….	Enter…	Result
	MASS kg/m2	DEPTH cm	FREQ
	4	5	134.2
	4	10	94.9
	4	15	77.5
	4	20	67.1
	4	25	60.0
	4	30	54.8
	4	35	50.7
	4	40	47.4
	4	45	44.7
	4	50	42.4
	Imperial		
	Enter….	Enter…	Result
	MASS lb/ft2	DEPTH in	FREQ
	0.8	2	134.4
	0.8	4	95.0
	0.8	6	77.6
	0.8	8	67.2
	0.8	10	60.1
	0.8	12	54.9
	0.8	14	50.8
	0.8	16	47.5
	0.8	18	44.8
	0.8	20	42.5

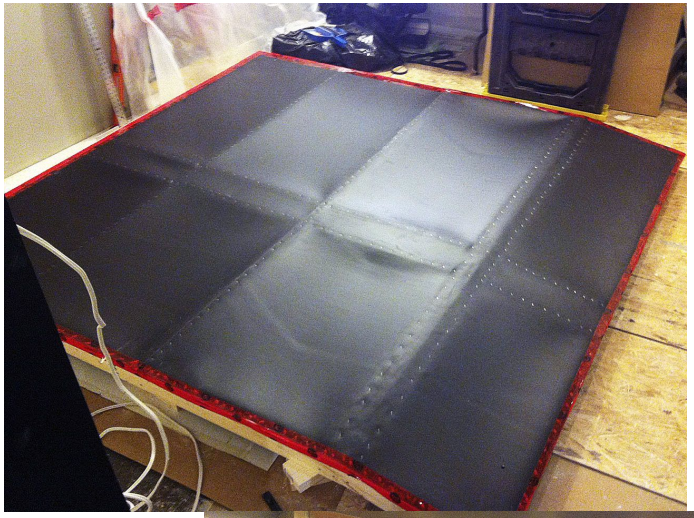
https://www.gearslutz.com/board/showpost.php?p=8041687&postcount=1

Membrane

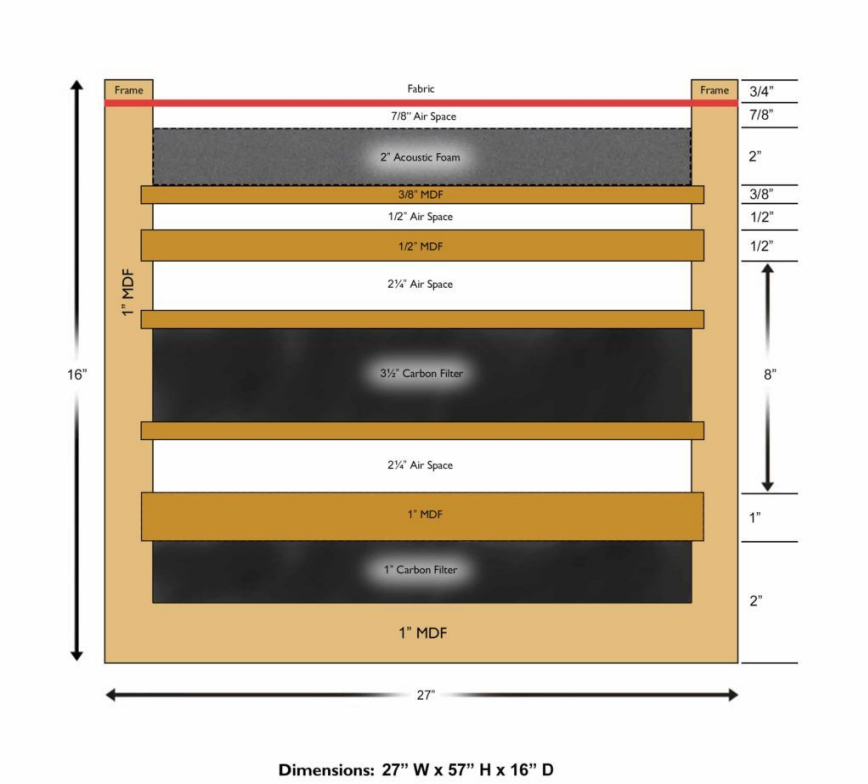


https://www.gearslutz.com/board/bass-traps-acoustic-panels-foam-etc/743040-tims-limp-mass-bass-absorbers-31.html

Membrane



Variation on the Membrane Absorber: Diaphragmatic Absorber



https://www.acousticfields.com/diy-plans-for-absorbers-and-diffusors/

Operating principal is mass and stiffness of its materials. Responds to most prevalent frequency build up in a room rather than having a "tuned" frequency

https://www.acousticfields.com/from-room-noise-to-solution/

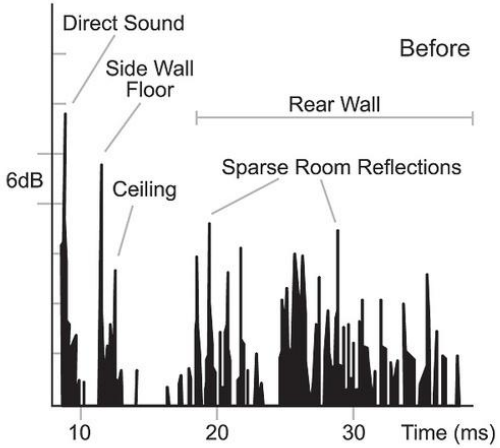
F) Diffusion

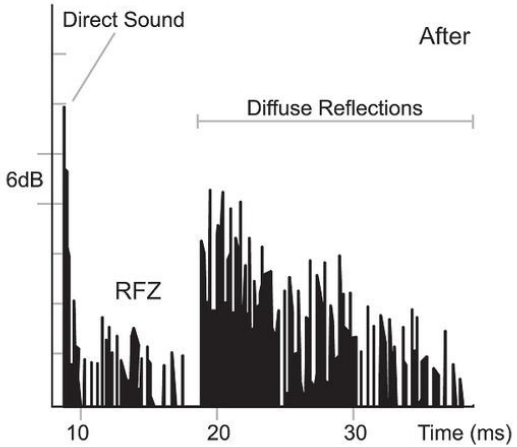
Uses:
-break up hard reflections by diffusing the reflected energy over a wide area, rather than bouncing it straight back like a mirror.

-easy to soak up mid-high frequencies with absorption, diffusion scatters these frequencies creating a ‘live’ sound to the room

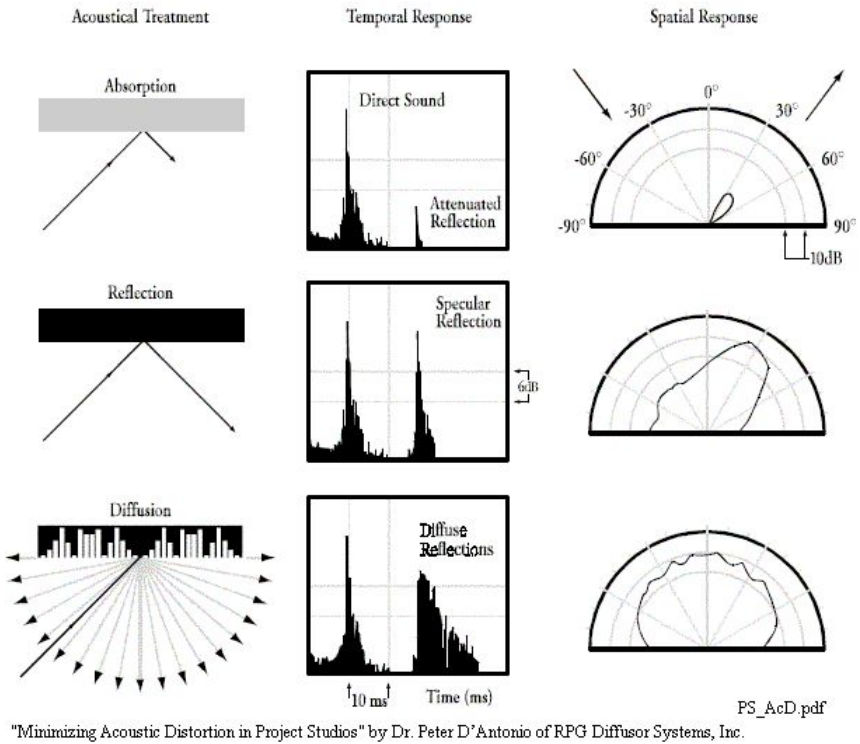
https://www.soundonsound.com/sound-advice/q-when-are-diffusors-good-idea

F) Diffusion



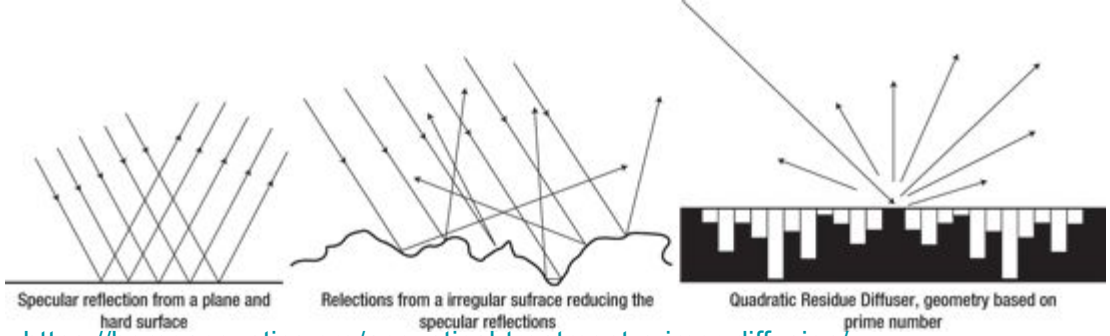


https://www.soundonsound.com/techniques/sos-guide-control-room-design

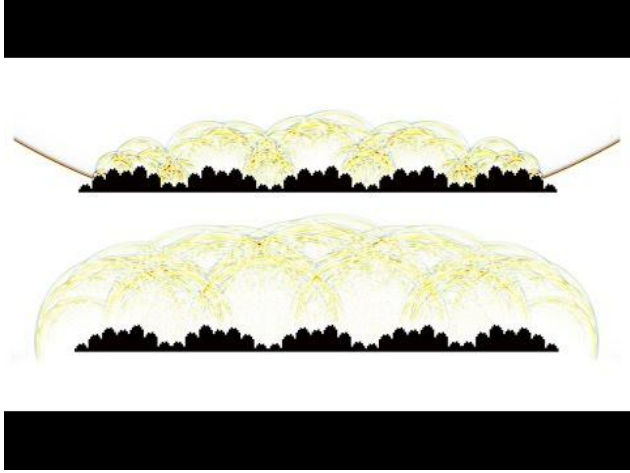


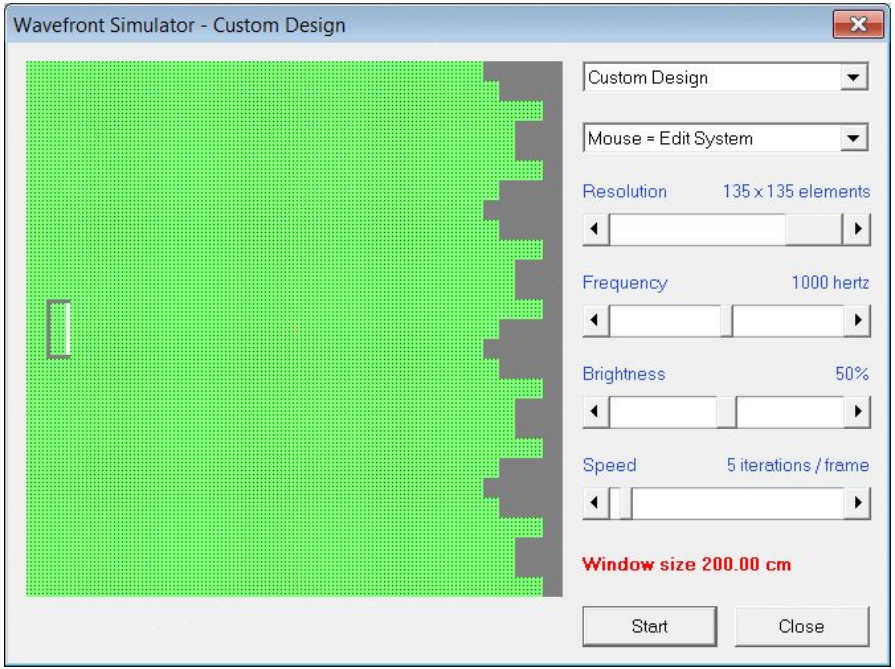
"Minimizing Acoustic Distortion in Project Studios" by Dr. Peter D'Antonio of RPG Diffusor Systems, Inc.

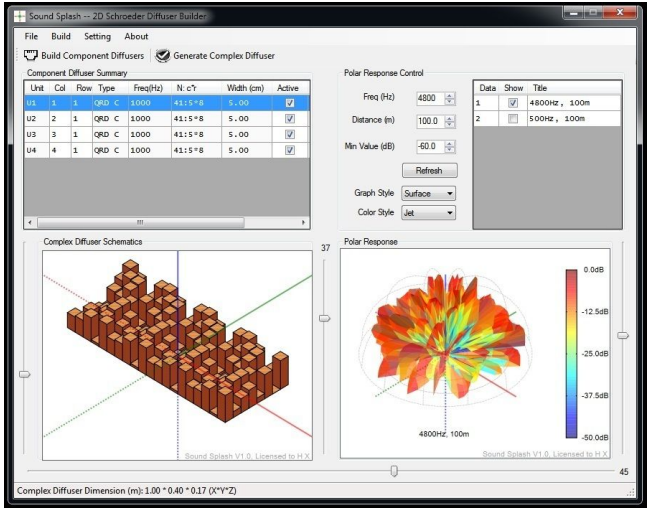
https://www.concepcaoacustica.com/post/o-que-voc%C3%AA-precisa-saber-sobre-difus%C3%A3o-e-absor%C3%A7%C3%A3o



https://homeacoustics.org/acoustical-treatment-primer-diffusion/



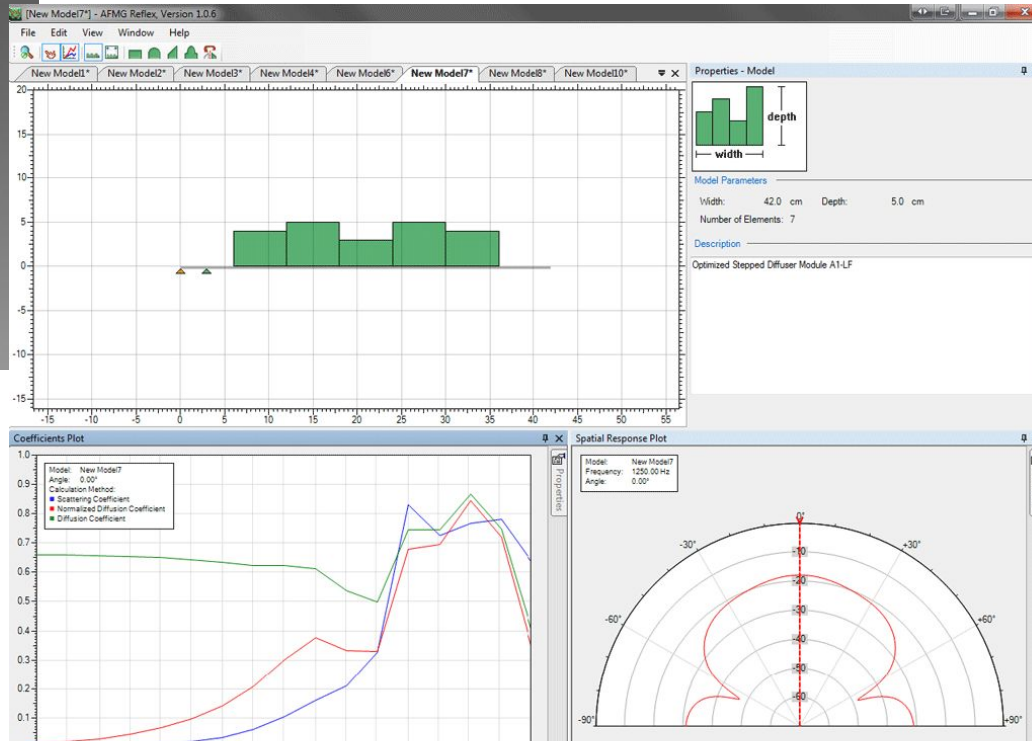




http://www.hxaudiolab.com/sound-splash.html

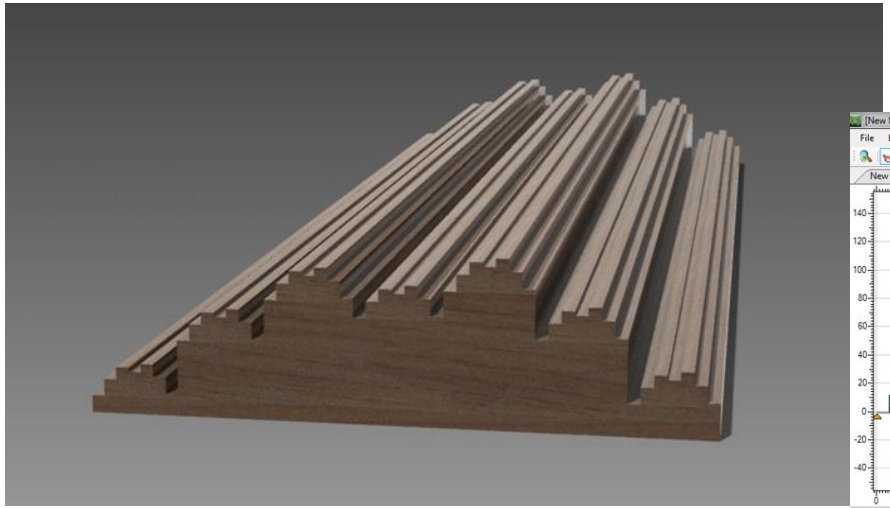
https://www.diyaudio.com/forums/room-acoustics-and-mods/308752-simulating-sound-diffuser.html

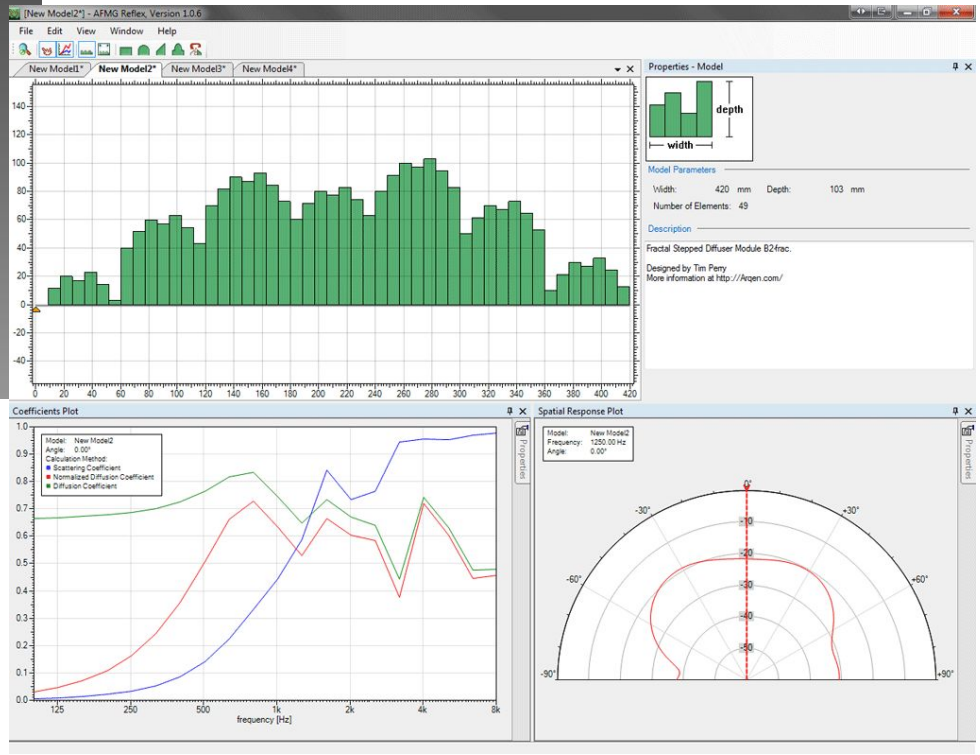
Stepped Diffusers



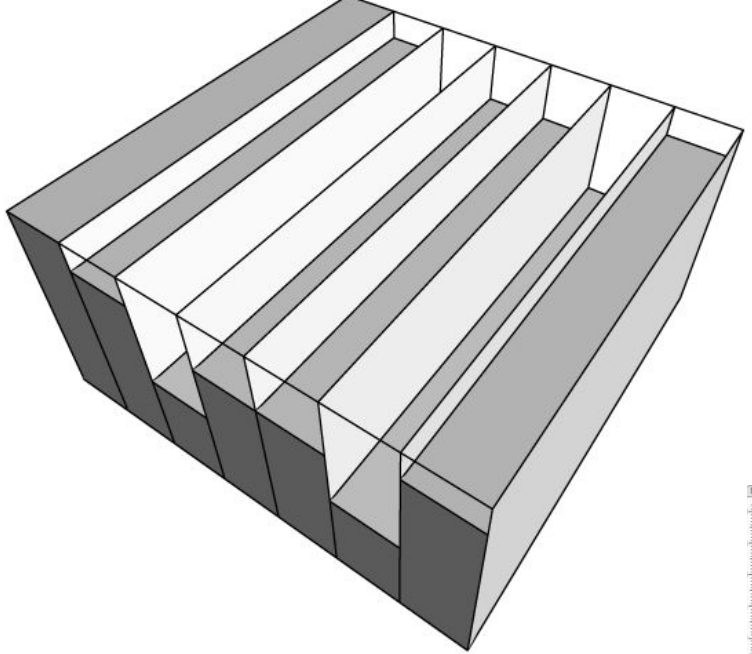
http://arqen.com/sound-diffusers/

Fractal Diffusers



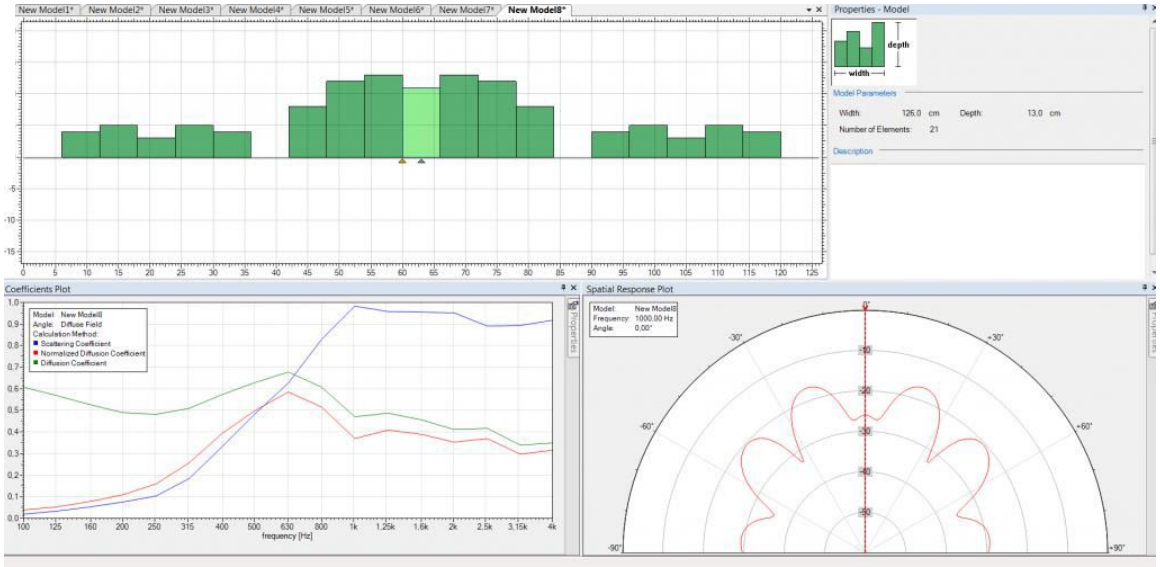


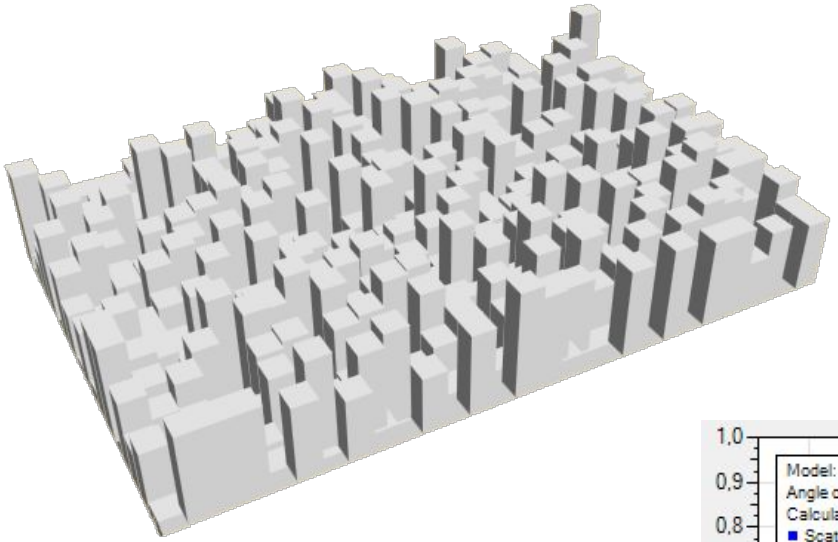
http://arqen.com/sound-diffusers/



Quadratic Diffusers

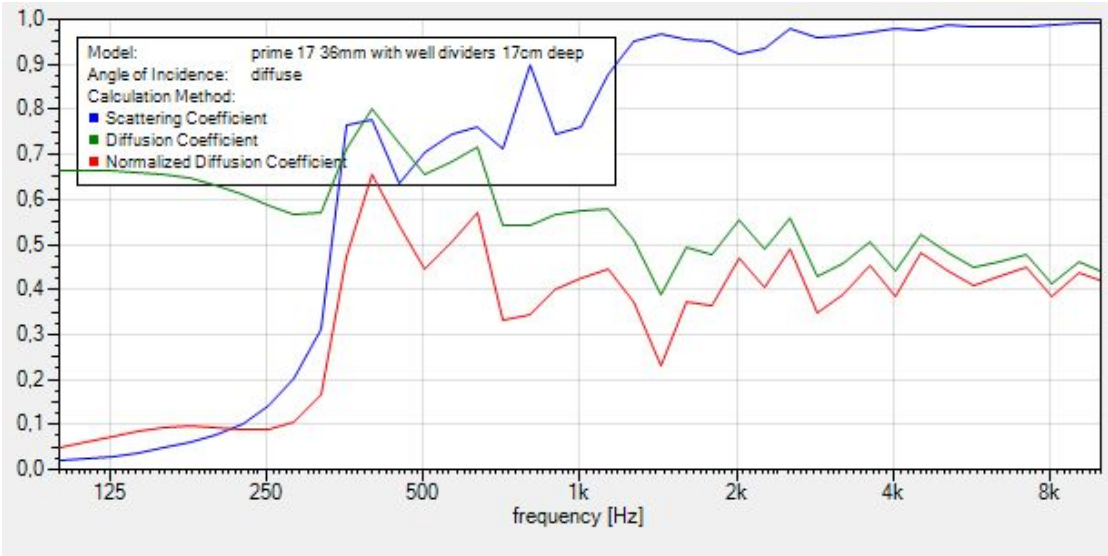
http://argen.com/sound-diffusers/





Primitive Root Diffusers
(Skyline Diffuser)

http://argen.com/sound-diffusers/



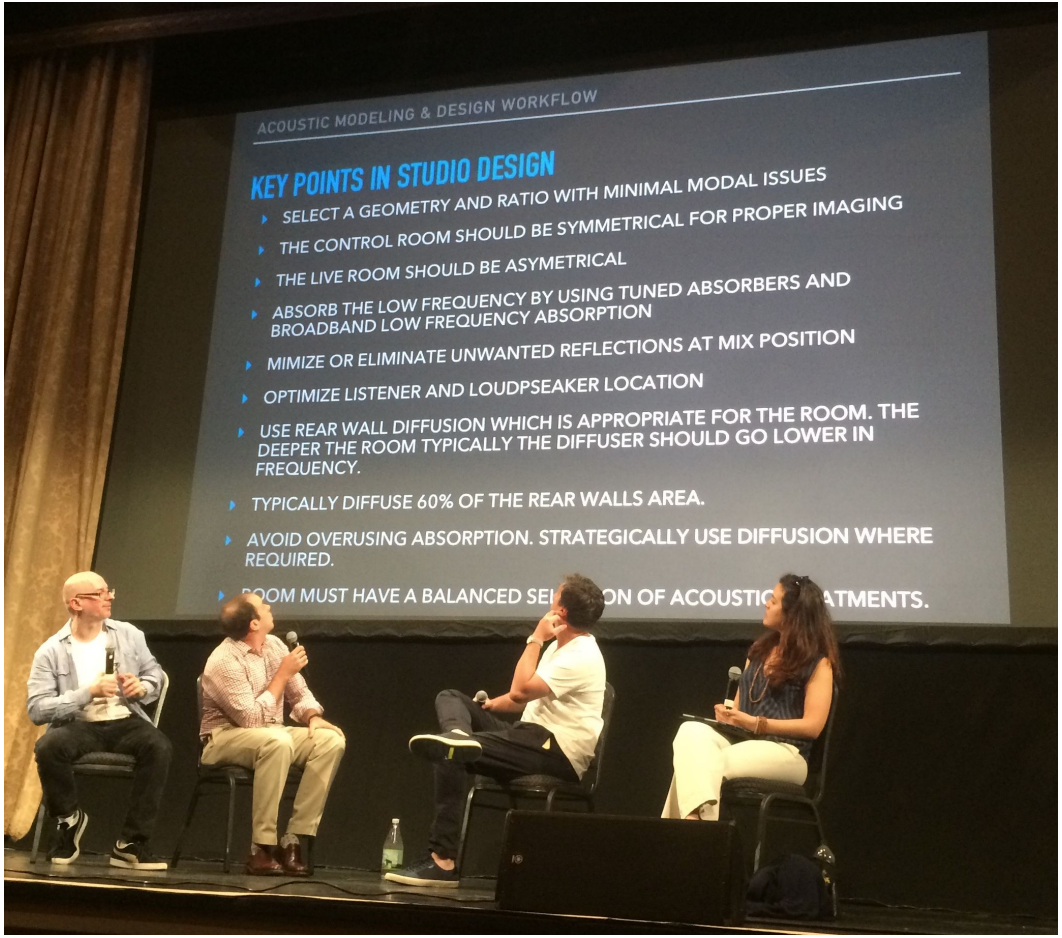
A few ideals:

-early reflections to be 15 dB lower than direct signal

-even reverberation time across the frequency spectrum (+-2dB)

-depending on room size RT60 value from 100ms-500ms

Conclusion:



"Room must have a balanced selection of acoustic treatments."

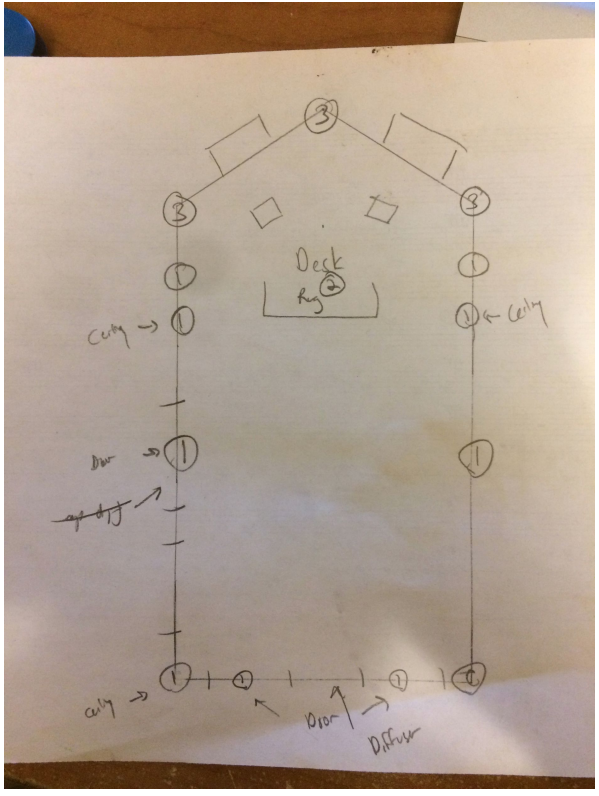
Mixcon 2017 in NYC: The "Improve Your Mix Room!" session with Sonic Scoop's David Weiss, Dave Kotch of Criterion Acoustics, Jim Keller of Sondhus & Rachel Alina.

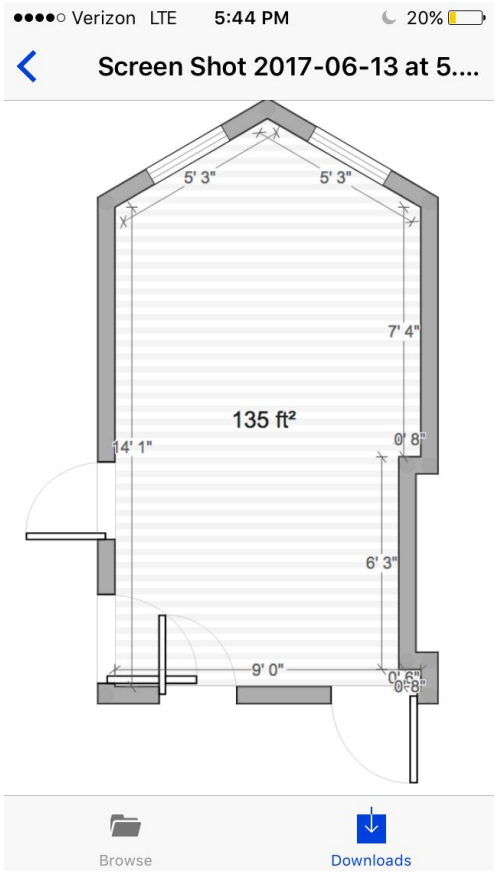
My Own Experiment / Adventure

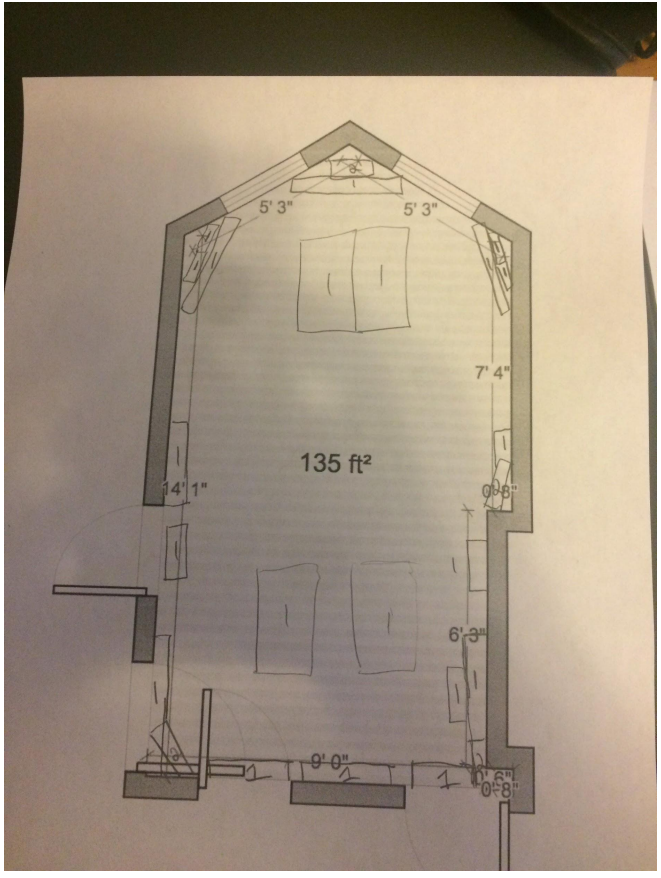
Goal: Place broadband absorption panels strategically in my room & build a diffusion panel. Do it as cheaply as possible.

Before (had just gotten 6 OC 703 4” panels):

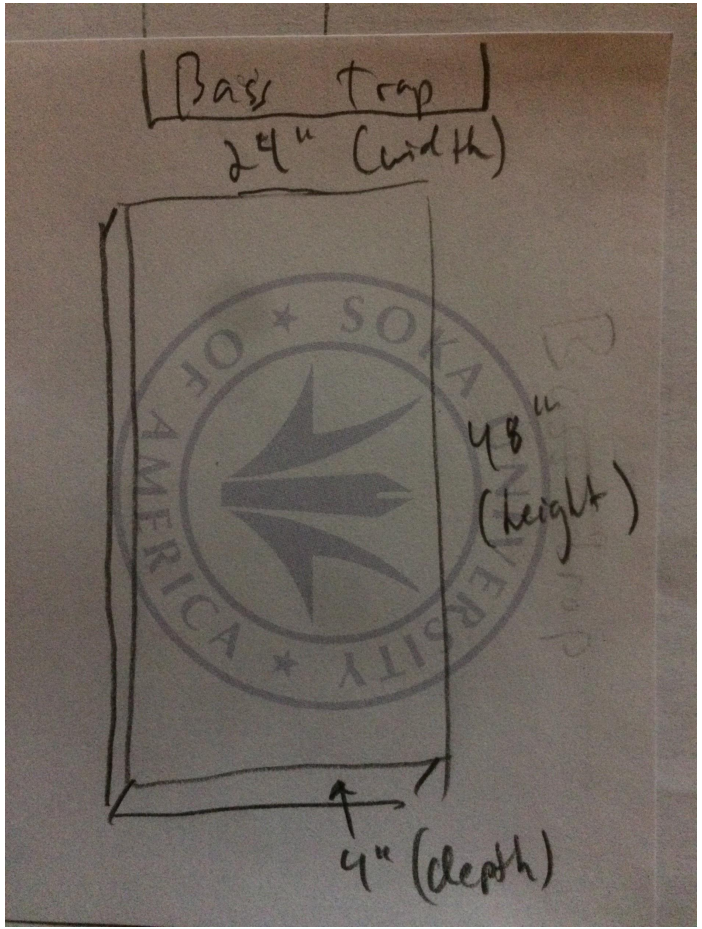
Planning:

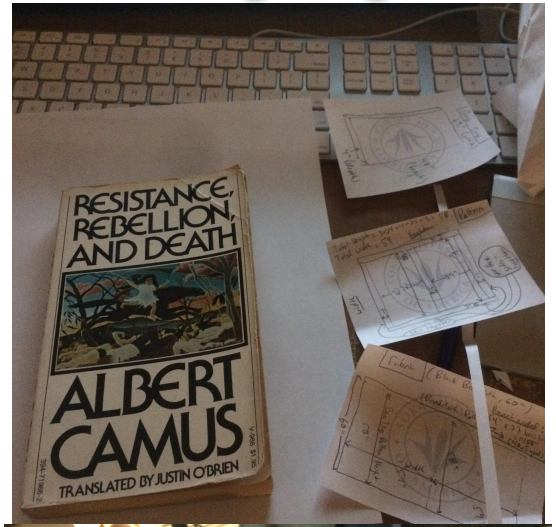

Deck
Diffuser

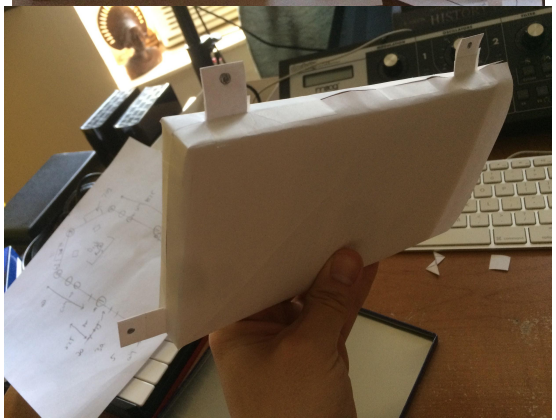

Verizon LTE 5:44 PM 20%
Screen Shot 2017-06-13 at 5....
5' 3"
5' 3"
7' 4"
135 ft²
14' 1"
0' 8"
6' 3"
9' 0"
0' 6"
0' 8"
Browse
Downloads

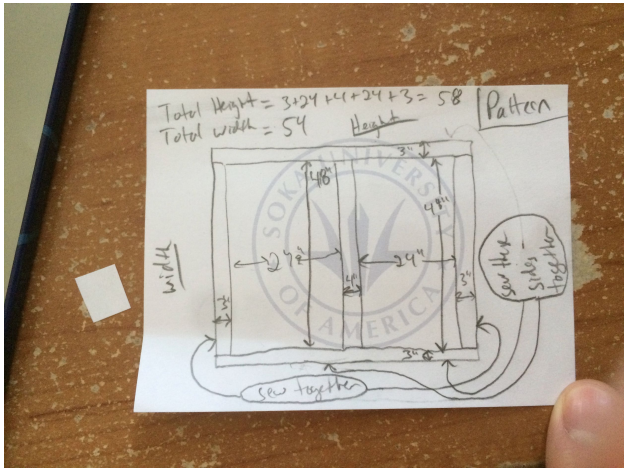

5' 3"
5' 3"
7' 4"
135 ft²
14' 1"
6' 3"
9' 0"
0' 8"

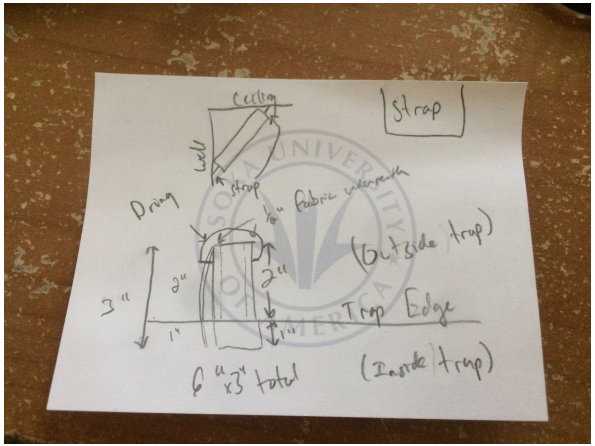
Designing:


Bass Trap
24" (width)
48" (height)
4" (depth)

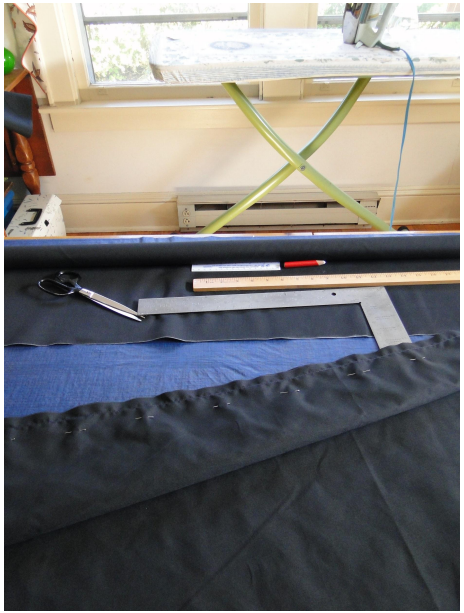

RESISTANCE, REBELLION, AND DEATH
ALBERT CAMUS
TRANSLATED BY JUSTIN O'BRIEN




Pattern
Height
Width
sew together

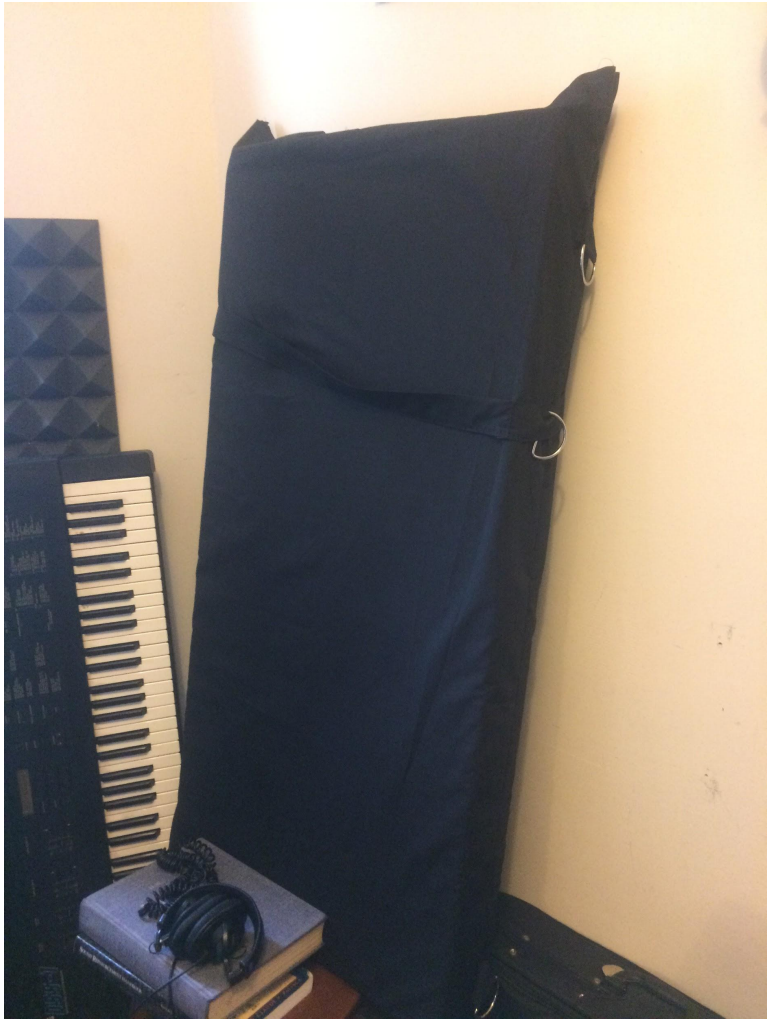

strap
ceiling
wall
strap
Drop
6" fabric underneath
(outside trap)
2"
3"
Trap Edge
1"
6" x 3" total
(Inside trap)

Sewing:



OC 703 Delivered

Panels unpacked, placed in fabric encasements



Quadratic Diffuser Build


RYOBI

Diffuser Plans:
https://www.acousticfields.com/product/all-in-one-diy-acoustic-treatment-build-plans-package/

Diffuser Finished

Absorption Price List

•6 x 4” Owens Corning 703 from Amazon = $227 ($38 ea)
(https://www.amazon.com/Owens-Corning-Fiberglas-Acoustic-Insulation/dp/B07XTM1DL9/ref=sr_1_2?keywords=4%E2%80%9D+Owens+Corning+703&qid=1579117787&sr=8-2)
•24 x 4” Owens Corning 703 from from MSC = $595 ($24 ea)
(http://www.metrosupplycollc.com/)

•59 Yards BroadCloth Fabric = $126
(https://www.fabricwholesaledirect.com/products/cotton-polyester-broadcloth-fabric-60-inches)
•140 2” D-rings = $94
(https://www.strapworks.com/Metal_D_Ring_p/mdr.htm)
•200 Tea Cup Hooks = $8
•225 Safety Pins = $6

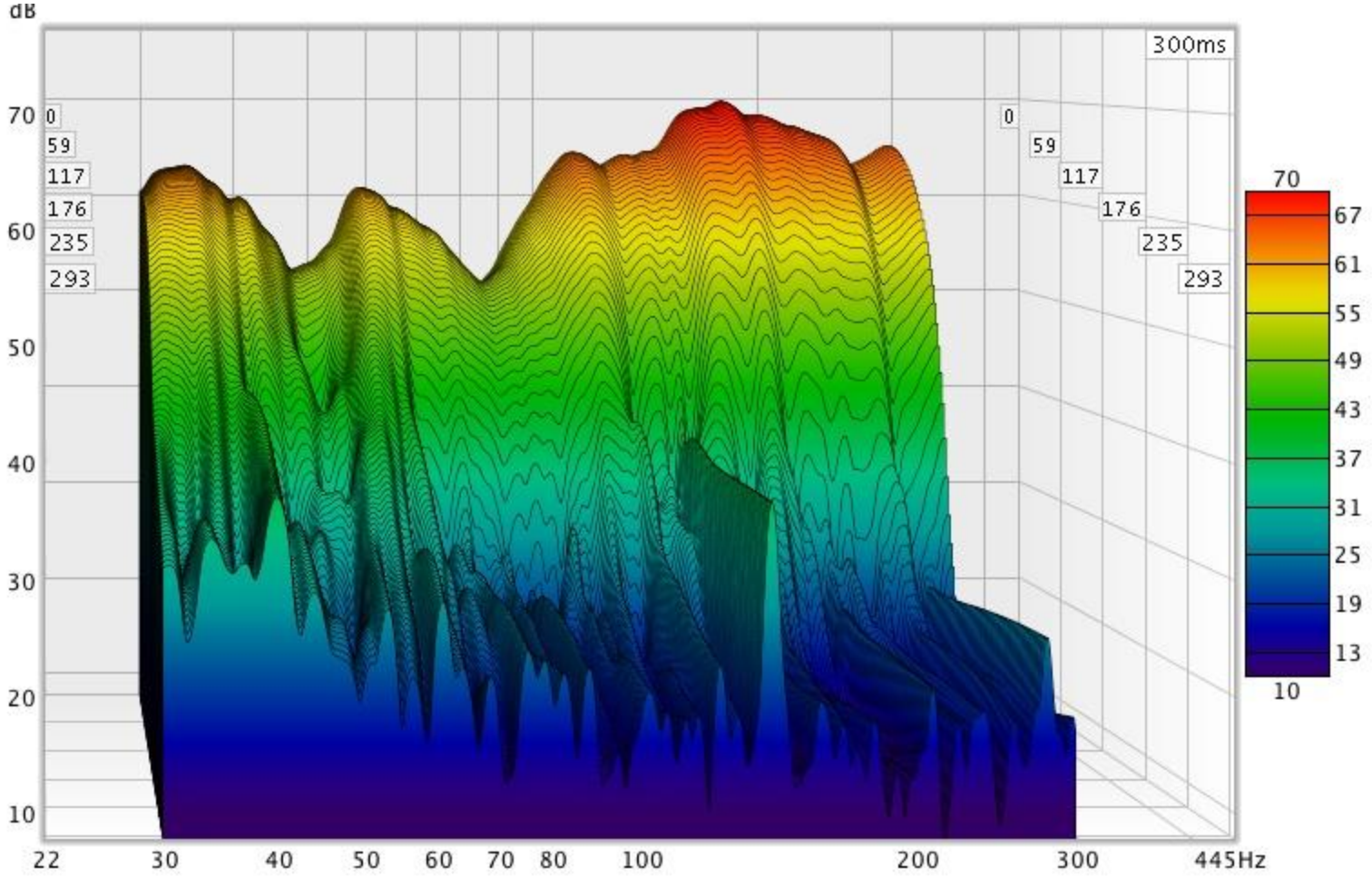
Total: $1056

Diffusion Price List

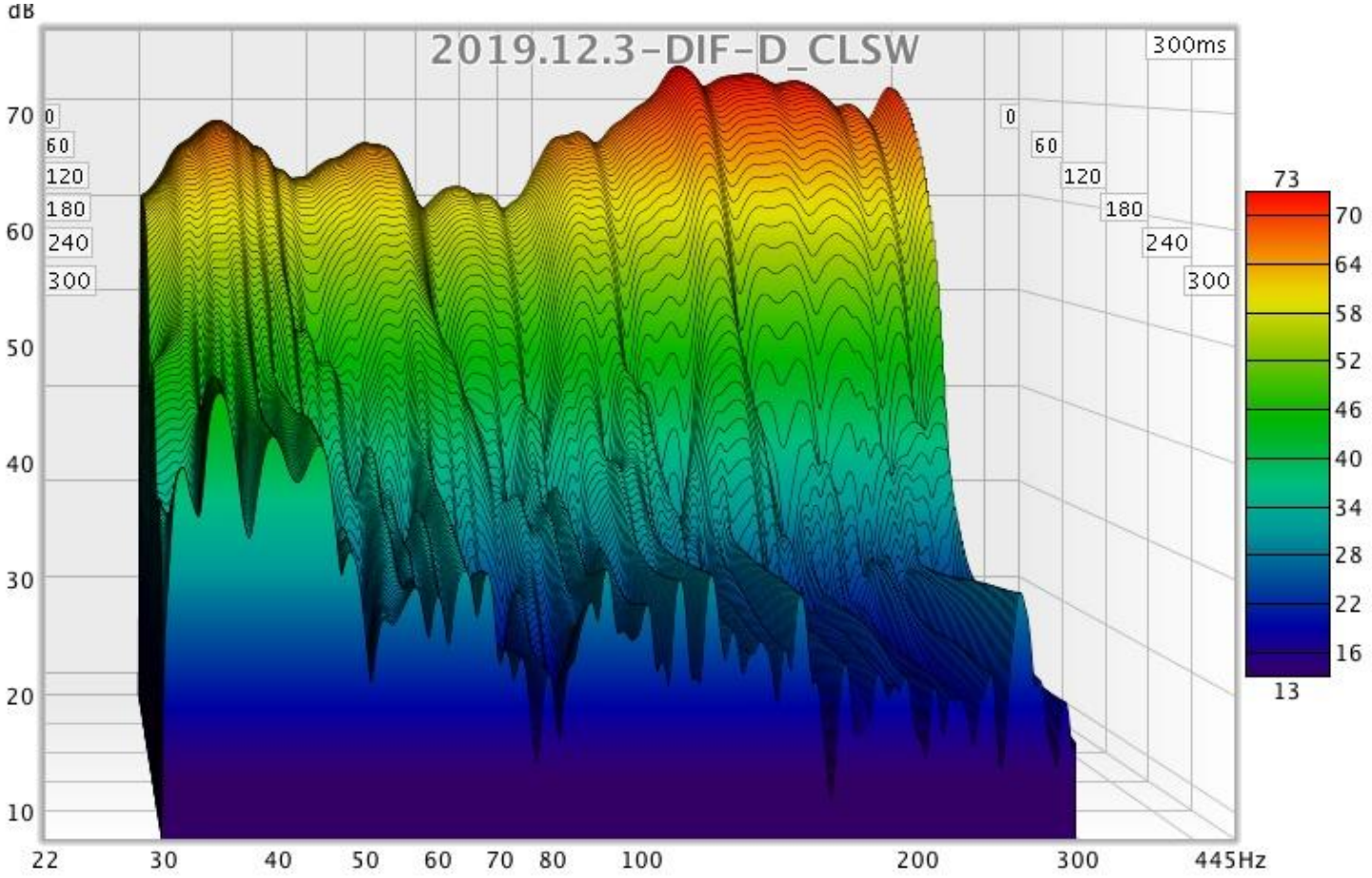
Wood = $277
Misc stuff from Home Depot = $93
Plans from Acoustic Fields = $27
(https://www.acousticfields.com/product-category/d-i-y-acoustic-treatment/)

Total = $397

BEFORE TREATMENT



AFTER TREATMENT



AFTER TREATMENT - WITH SONARWORKS