Project Studio Acoustics

Solutions for better sounding rooms

Housekeeping

- Please turn off cell phones
- We have lots to cover!
- Please keep questions on track

Introduction

- We WILL talk about the acoustics of project studios
- We will NOT talk about concert hall or church acoustics
- Shortened version of AES T3 and T5 Tutorials
- 4:1 compression !!

Project Studio Statistics

- 350,000 project studios worldwide
- 93% of A titles go through project studio at some phase of production
- In homes, in studios, in post-production facilities
- Translation to the outside world at issue!

2 Types of rooms

- Sound Production
  - Acoustics of room contribute to the character of the recorded sound
- Sound Reproduction
  - Acoustics of room provide a neutral environment to audition pre-recorded sound
  - Let's talk about this

Introduction

- Why talk about acoustics?
- Acoustics are audible!
- Contribute to over 50% of quality
- Acoustics are fixable

What's Acoustics?

- It's about the speaker/room/listener interface
- It's what separates "Major" studios from "Project" studios
- It's today's key issue!

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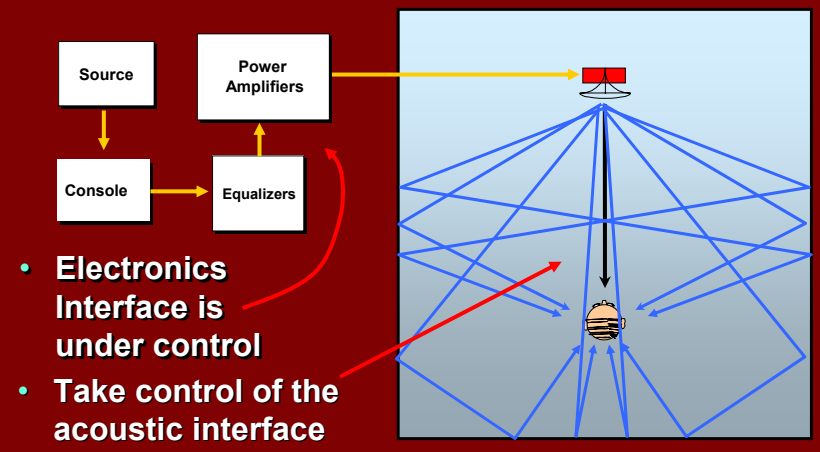
The Acoustic Interface



- Electronics Interface is under control
- Take control of the acoustic interface

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Warning !

Room acoustics will
mess you up !

Acoustical Issues

1. Room reflections
2. Room echoes
3. Reverberation time
5. Standing waves
6. Rattles
7. Background noise
8. Sound Isolation

Acoustic

The Design Process

The Design Process

1. Dimension the room
2. Sound isolation
3. Noise control
4. Vibration control
5. Model decay time
6. Determine absorption area
7. Determine diffusion area
8. Determine treatment locations
9. Treat echoes
10. Place listener
11. Place sound system
12. Tune it all

... But First a Bit of Theory

- Sound is
  - Vibrating air
  - Changing pressure
  - Perceived by our ear-brain
  - Frequency of pressure changes determines pitch

Acoustic Wavelength

Sound Propagates at 1.13ft/msec

$$\text{Wavelength} = \frac{1130}{\text{Freq}}$$

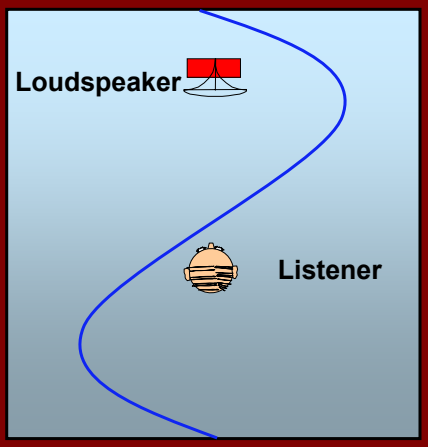
Room Dimensioning

Standing Waves

Room Dimensioning

- How much room do you have?
  - I cant help you!
- Standing waves
  - I can help!

Standing Waves
a.k.a. Room Modes

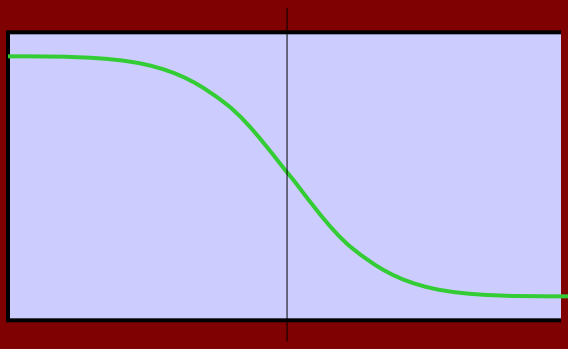


- Standing waves happen when room dimension is equal to sound wavelength
- Also at 0.5, 1.5, 2, 2.5, 3, etc. times wavelength

Standing Waves

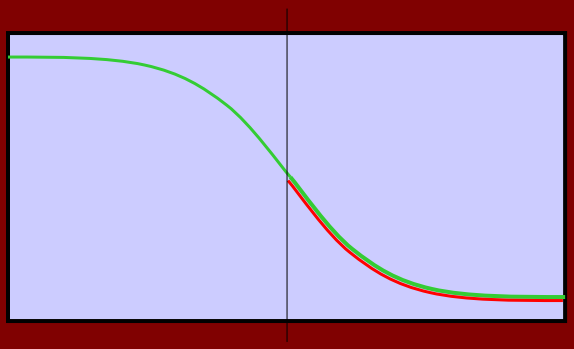
- Standing waves cause
  - Resonances
  - Uneven frequency response
  - Poor bass impact
  - Different bass at each seat
  - Common problems are in the 30 Hz to 150 Hz range

A Resonant frequency



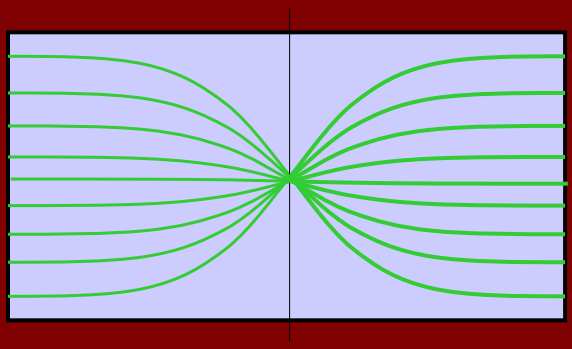
- No wall; no reflection

A Resonant frequency



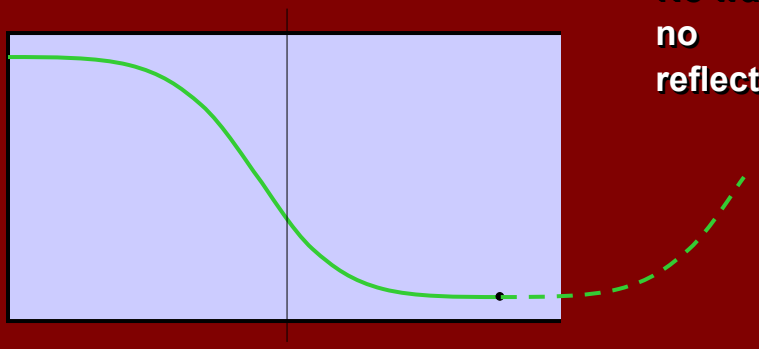
- After reflection, signal nulls overlap

A Resonant frequency



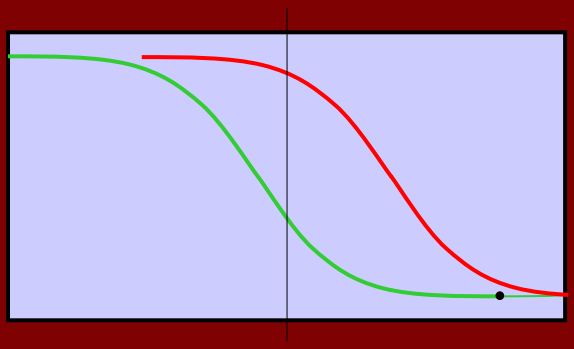
- After reflection, signal nulls overlap

A Non-Resonant frequency



- No wall; no reflection

A Non-Resonant frequency



- No null overlaps

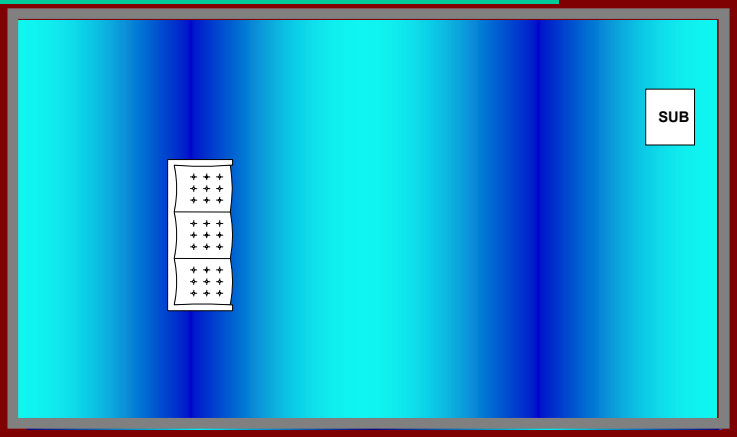
Standing Waves

- Standing waves are a product of the room dimensions
  - All rooms will have some standing waves
  - Resonance overlaps are the result of the ratio of the room dimensions
- Intensity of room modes is determined by the wall density and stiffness

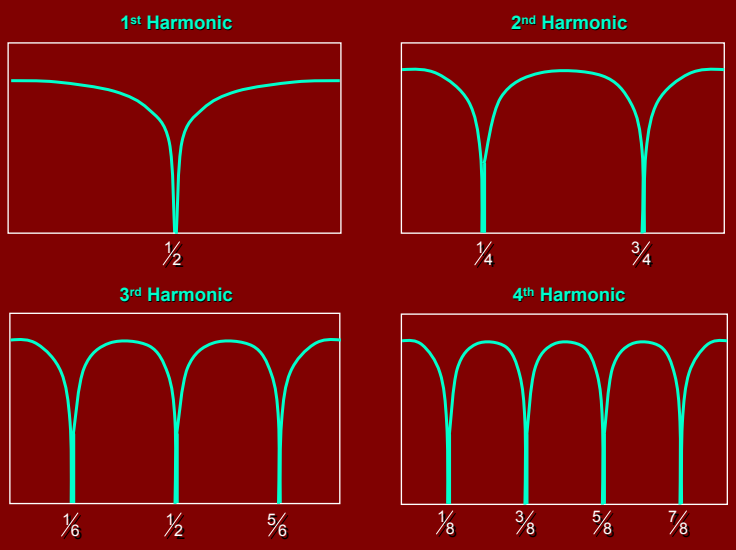
Standing Waves (continued)

- Standing wave modes are
  - Axial – The most important ones
    - Between two opposite walls
  - Tangential – Not important
    - Between two pairs of walls
  - Oblique – Not important
    - Between all room surfaces

Standing Waves
A Second Harmonic Length Axial Standing Wave

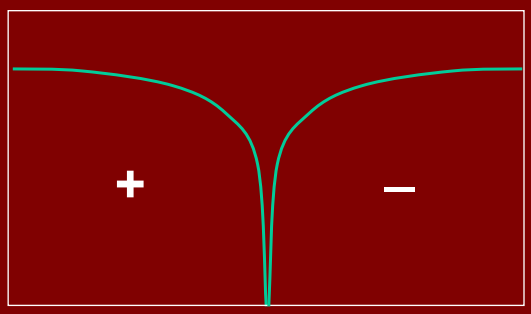


Standing Waves Pressure Representation for 1st, 2nd, 3rd, 4th Harmonics



Standing Waves Pressure Polarity

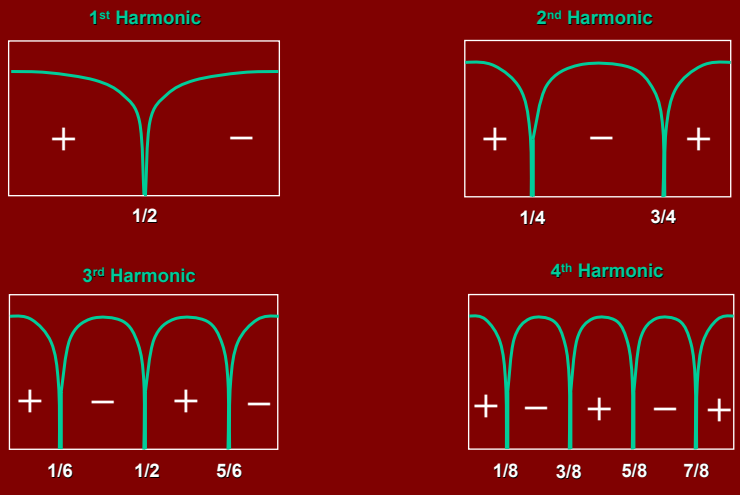
1st Harmonic



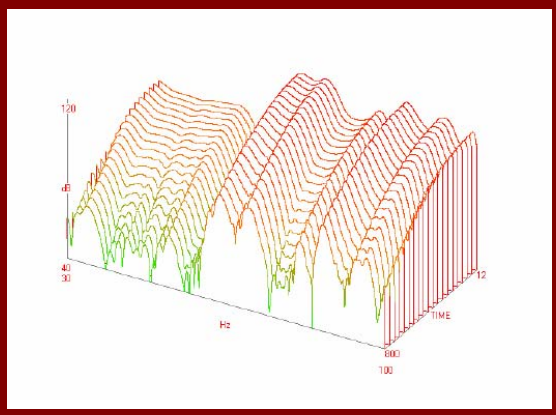
1/2

- The acoustic polarity changes around the null

Standing Waves
Pressure Polarities



Standing Waves
Modal decay



- Example of room modal decay plot
- Long decay
- Most audible effect of room modes

Ways to Deal With Standing Waves (Room Modes Can Never Be Eliminated)

- Change one or more dimensions
  - Minimizes resonance pile-ups
  - Aim for even modal distribution (>5% difference)
- Move subwoofer location
  - Drive mode out-of-phase to reduce relative amplitude
- Use bass absorption or absorptive walls
- Move seating location
  - Moves the listener out of peaks and dips
- Equalize

Standing Waves Resonance Frequencies

Equation:

$F = n1130/2D$ (in ft)
$F = n345/2D$ (in m)

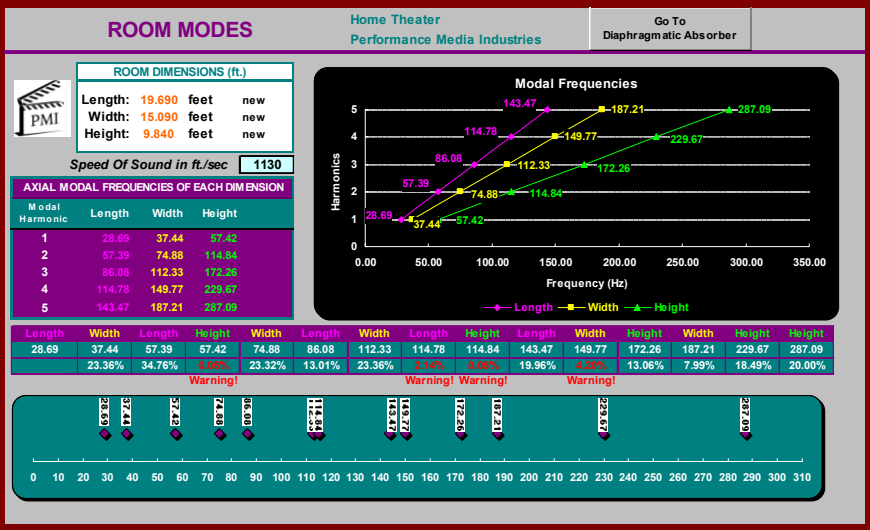
Where F is frequency
n is the harmonic
D is the distance between walls

Solutions to Standing Waves
Room Dimensions

- Determine room dimensions
- Determine modes (F=n1130/2d)
- Find modal overlaps
- Locate dips for 1st, 2nd, 3rd, 4th harmonics

Solutions to Standing Waves
Room Dimensions (continued)

- Calculation programs
  - RPG Room Optimizer
  - CARA
  - THX Room Mode Calc
  - Stereophile Guide to Home Theatre
  - PMI modeling program

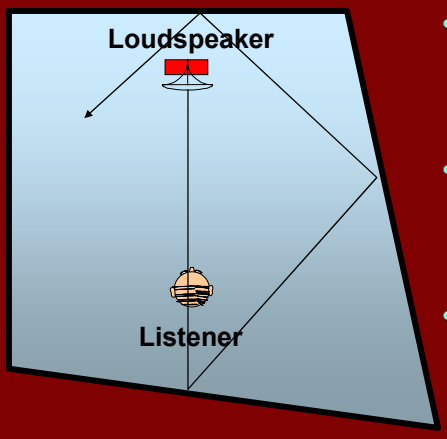


Solutions to Standing Waves Room Dimensions

- For room dimensions that are “useable” this guideline is handy
- 1.1w/h ≤ l/h ≤ 4.5 w/h - 4 and w < 3h and l < 3h
- Where l = length, w = width, and h = height
- l, w, and h which are within ±5% of integer values should be avoided

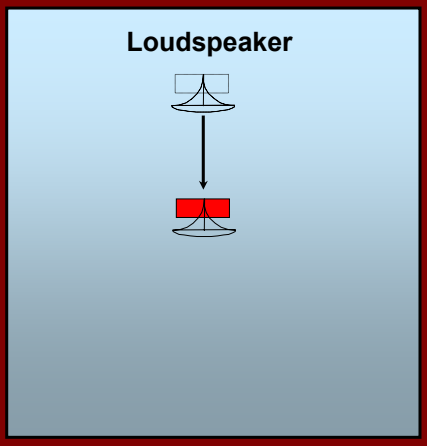
Source: Robert Walker, BBC, “EBU Technical Bulletin” 3276-E

Solutions to Standing Waves
Room Shapes



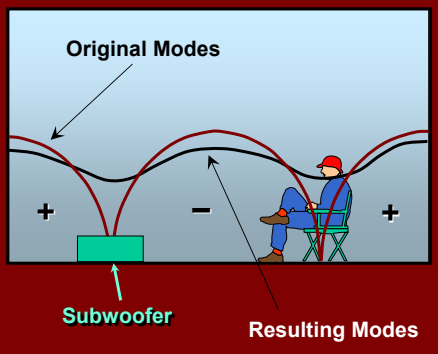
- Complicates Acoustic modeling and computations
- Doesn't get rid of standing waves or reflections
- Not recommended

Solutions to Standing Waves
Subwoofer and Speaker Placement



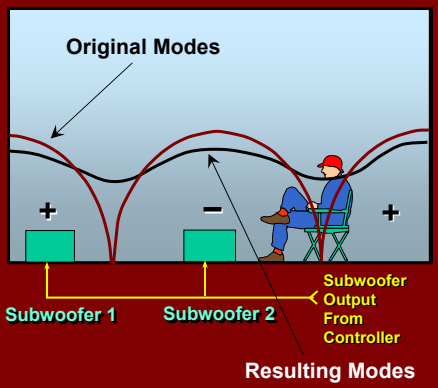
- Driving room standing waves in cancellation areas can improve response

Solutions to Standing Waves
Placement — 1 Subwoofer



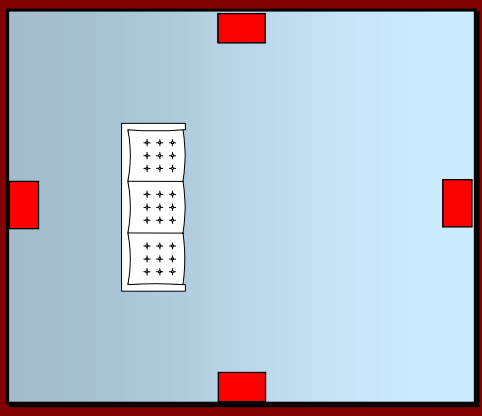
- How to improve a 2nd order standing wave
  - The subwoofer drives the + and - areas equally, resulting in reduction of resonance

Solutions to Standing Waves
Placement — 2 Subwoofers



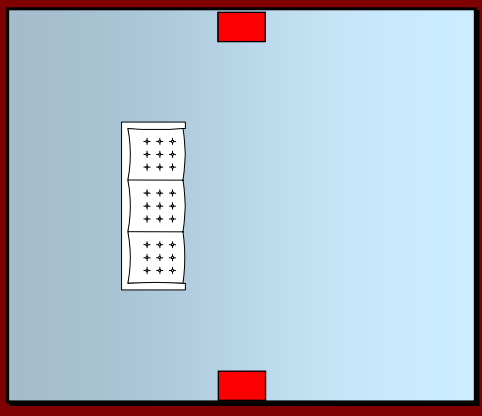
- Improving a 2nd order standing wave
  - Connect the 2 subwoofers together as "in-phase"
  - The 2 subwoofers drive the + and - areas equally, resulting in reduction of resonance
  - Experiment a lot

Subwoofer Placement
Reducing Standing Waves - A good solution



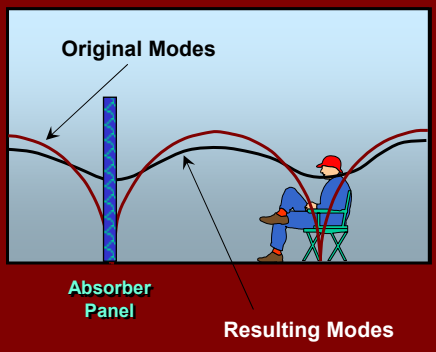
- 4 subwoofers
- They can be small and hidden
- It's the latest research findings
- Todd Welti et al.

Subwoofer Placement
Another good solution



- 2 subwoofers
- More SPL
- More standing waves

Solutions to Standing Waves
"Fuzz" Absorption at Standing Wave



- Place absorber panel at null (high velocity, low pressure area)
- PV = nRT !

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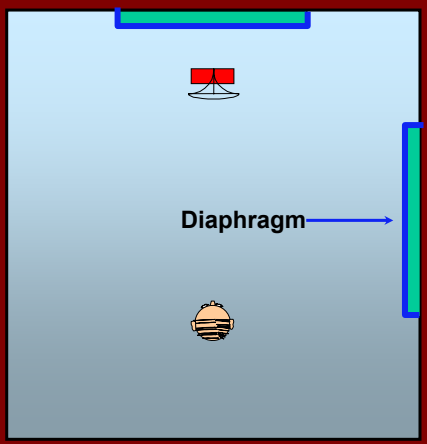
Solutions to Standing Waves
Diaphragmatic Absorption



- Absorber units are resonating material tuned to problem frequencies
- Absorber box is filled with "fuzz"
- Works up to 150Hz
- Design of bass absorber is complex — Use an acoustical consultant

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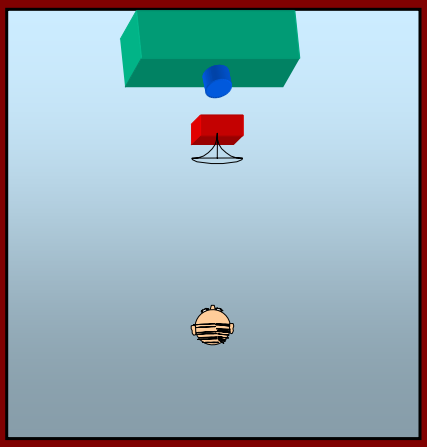
Solutions to Standing Waves
Helmholtz Absorption



- Helmholtz units are tuned to problem frequency
- Absorber box is filled with fuzz
- Works down to 80Hz
- Design of Helmholtz absorber is extremely complex

Solutions to Standing Waves
The SpringTrap

- Combination Pistonic resonator and Helmholtz absorber
- F_0 determined by Mass – Spring – Air
- Reliable and predictable

Solutions to Standing Waves
The SpringTrap

- Combination Pistonic resonator and Helmholtz absorber
- F_0 determined by Mass – Spring – Air

Solutions to Standing Waves
The SpringTrap

- Combination Pistonic resonator and Helmholtz absorber
- F_0 determined by Mass – Spring – Air

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Solutions to Standing Waves
The SpringTrap

- Front panel suspended on springs
- Port on bottom of cabinet

Solutions to Standing Waves
The SpringTrap

- Mineral wool inside cavity to widen resonance

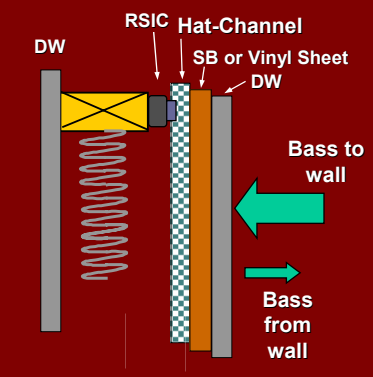
Solutions to Standing Waves
The SpringTrap

- Second chamber resonating port on bottom of cabinet
- Port extends up to middle of cabinet
- Optimized by PAM (Whise / Huon Labs)

Solutions to Standing Waves
The SpringTrap

- Two fundamental equations
- Ported resonant enclosure:
  - $F = (c/2pi)(A/L'V)^{1/2}$
- Spring loaded panel resonance:
  - $F = (1/2pi)(k/m)^{1/2}$
- Paper presented at AES 114th Convention, Amsterdam, March 2003
- Patent Pending

Solutions to Standing Waves
Resilient Walls



Wall with PAC RSCI-1 Isolators

- Resilient walls don't reflect bass well
- Sound energy is absorbed by the PAC RSIC rubber isolator
- Add Soundboard or Loaded Vinyl to spread the resonance frequency
- You get isolation too!

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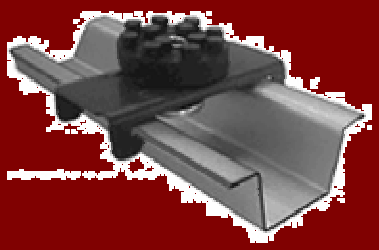
Solutions to Standing Waves
Resilient Walls PAC RSIC1



RSIC-1

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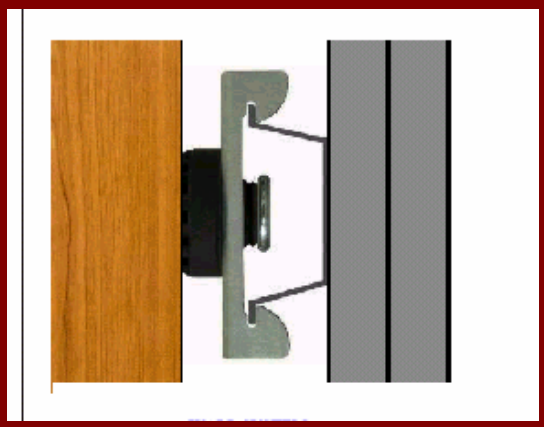
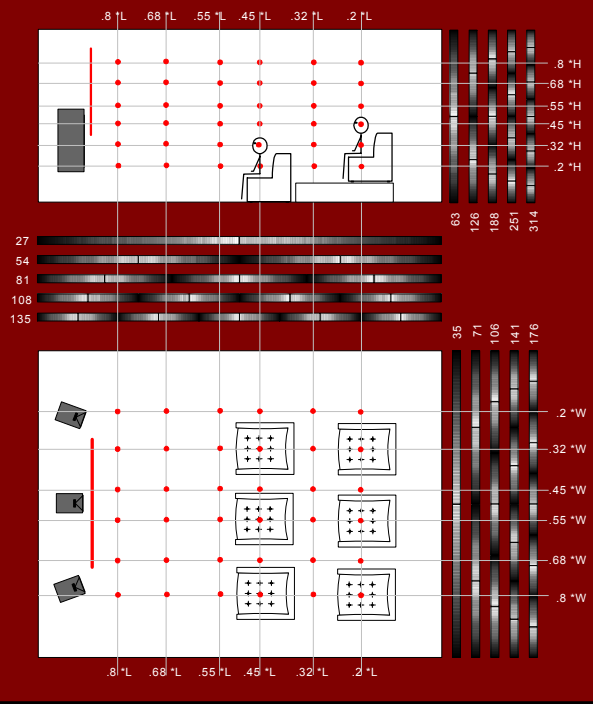
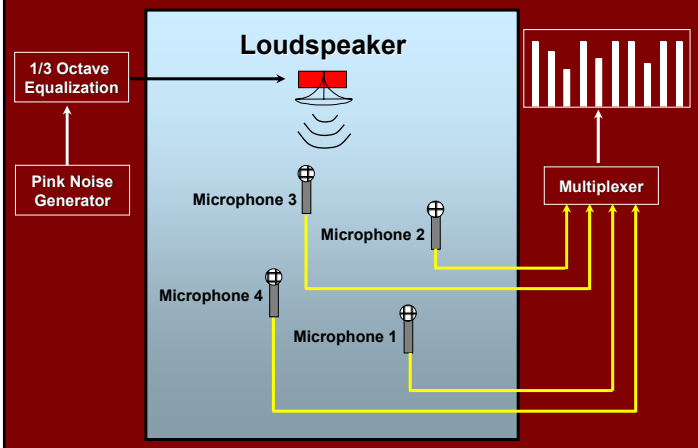
Solutions to Standing Waves Resilient Walls PAC RSIC1





Solutions to Standing Waves Seating Placement

Solutions to Standing Waves
Equalization



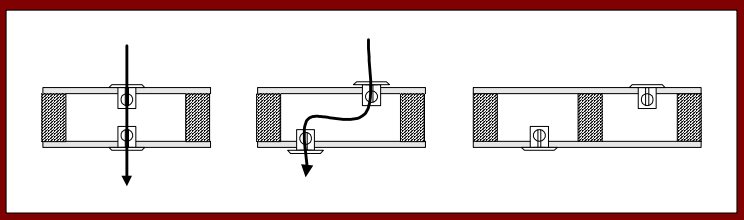
- Analysis should be spatially and temporally averaged
- Use Gold Line DSP30 Analyzer, or equivalent

Sound Isolation

Sound Isolation – 2 processes

- Sound leakage
  - Isolate doors, windows, and plumbing
  - Isolate, seal and caulk all leakage paths
- Mechanical Transmission
  - Special wall structures
  - Floating floor
  - Floating ceiling

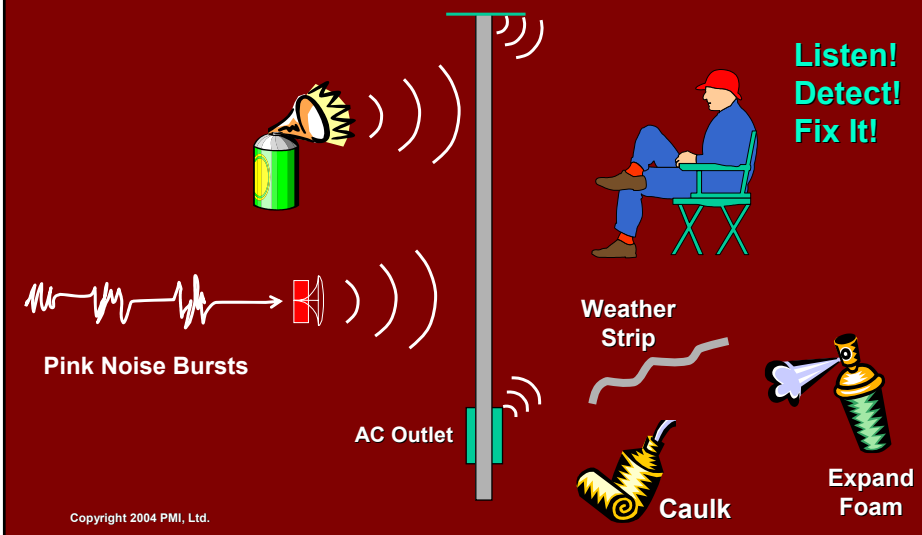
Isolate Flanking Paths



Full Flanking Offset Offset and Isolated

Isolate Flanking Paths

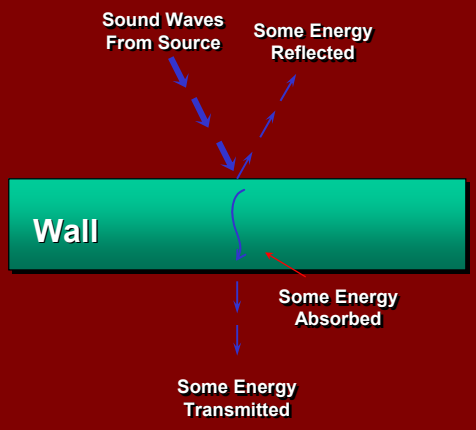
Noise Transmission Detection



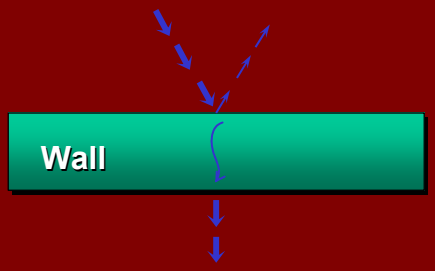
Isolation Solutions

Wall Construction

The Mechanism of Sound Transmission

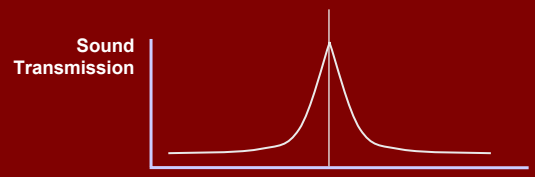


Wall Construction Resonance



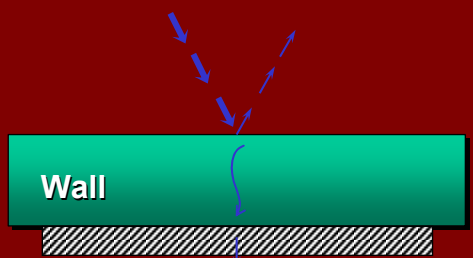
Sound transmission at resonance frequency

- All wall surfaces have a resonant frequency where they transmit lots of energy

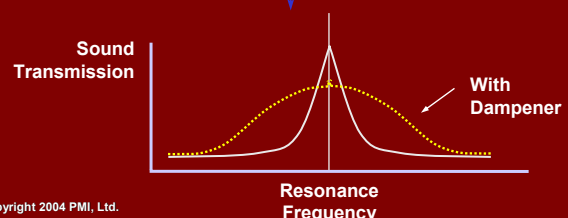


½" Drywall Example

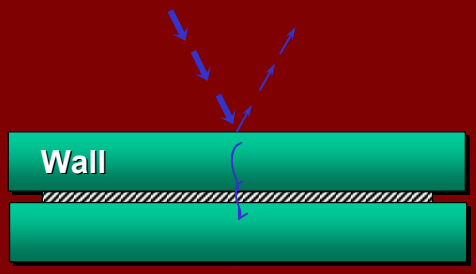
Wall Construction Damped Resonance



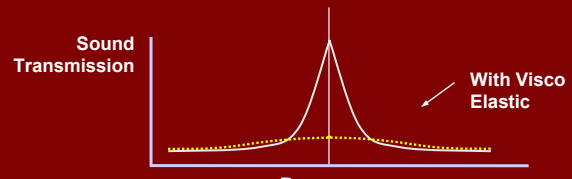
Loaded Vinyl barrier or Sound board



Wall Construction
Constrained Layer Damping

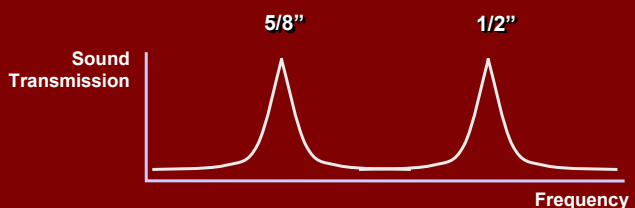


Visco-Elastic polymer



Wall Construction
Spread Resonance

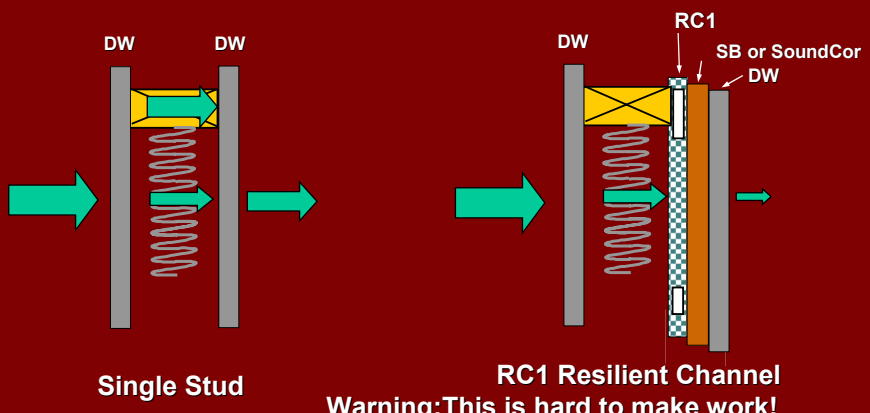
- Unequal thickness



Isolation Strategies

- More Mass
- Damp resonance
- Decouple
- Larger airgap

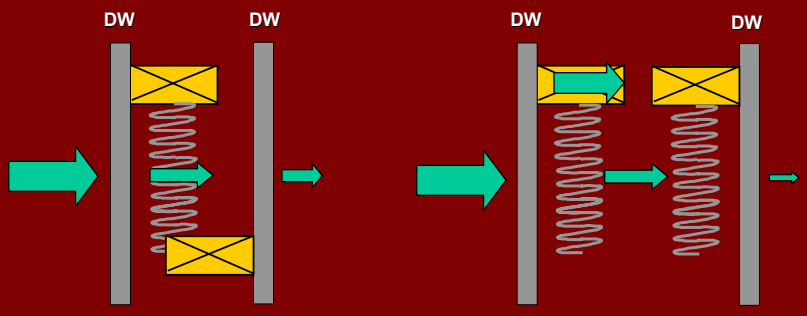
Wall Construction
Decoupling



Single Stud

RC1 Resilient Channel
Warning:This is hard to make work!

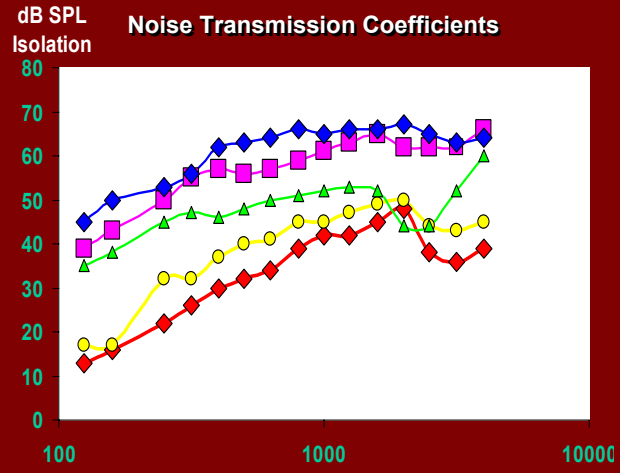
Wall Construction
Decoupling (continued)



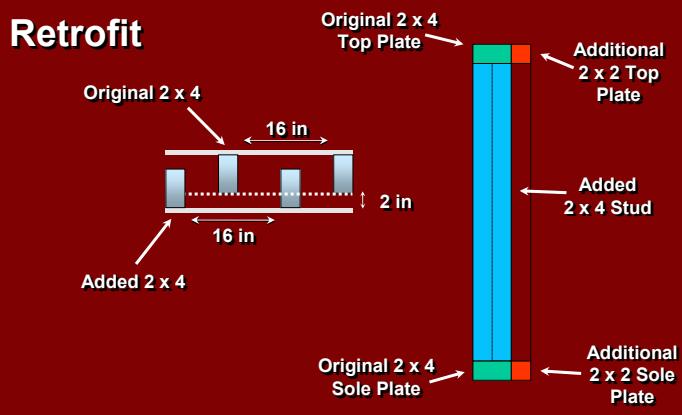
Staggered Stud

Double Wall

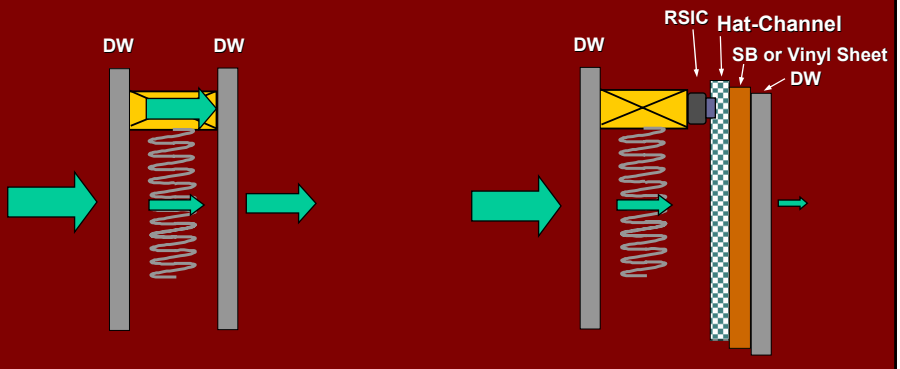
Studwall Isolation



Staggered Stud Construction



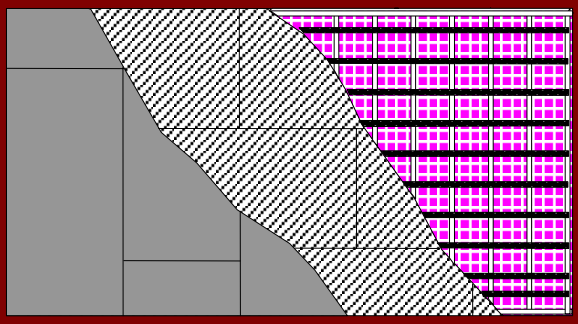
Suspended Wall Construction
PAC RSCI-1 "The little Miracle"



Single Stud
STC40

PAC RSCI-1 Isolators
STC 56 ! !

Wall Construction
Staggered Seams



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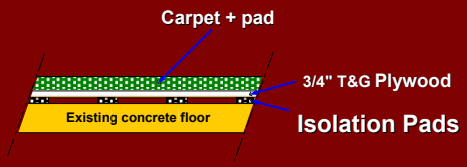
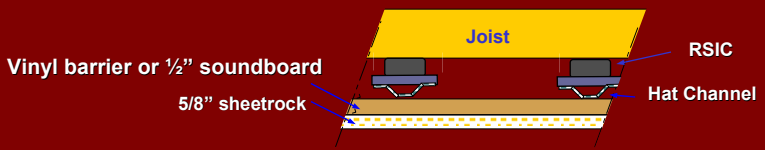
Isolating the ceiling and floor

- Floating floor construction



- Floating ceiling construction (PAC RSC-1 Isolators)



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Background Noise

Background Noise

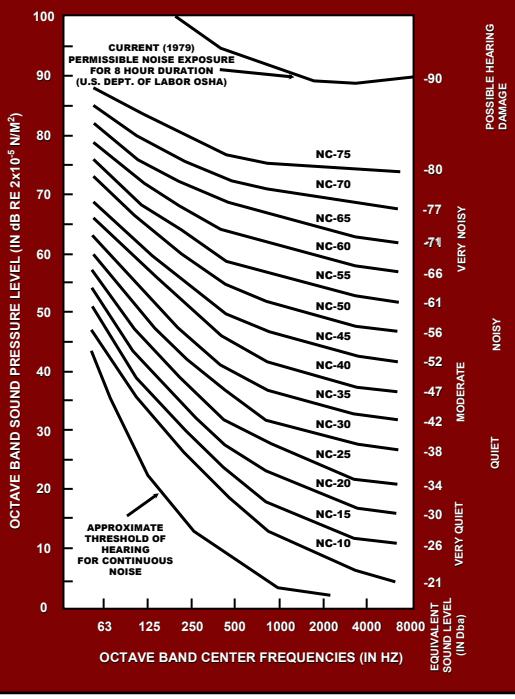
- Interferes with loudness perception
- Masks low level signals and detail
- Transient noise is distracting

Sources of Background Noise

- Local sources
  - HVAC
  - Plumbing
  - Fans
  - Pumps/Compressors
  - Washer/Dryers
  - Garage door openers
  - Projectors

Sources of Background Noise (continued)

- External sources
  - Traffic
  - Airplanes
  - Wind
  - Neighbors



Noise Criteria Curves (NC)

Targets:

NC25 for basic room

NC15 for High End room

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Measuring Background Noise

- Use spectrum analyzer
- Use a low noise microphone
- Take a time and space average
- Use NC weighting
- Plug your ears, wait, unplug and listen
  - Use Earplugs, or fingers

PMI

Solutions to Background Noise

- Large air ducts for lower air velocity
- Longer ducts with several turns
- Plenum silencers
- Lined ductwork
- “Whistle Free” air grilles
- Isolate motors on suspension or move
- Completely seal windows, doors, etc.

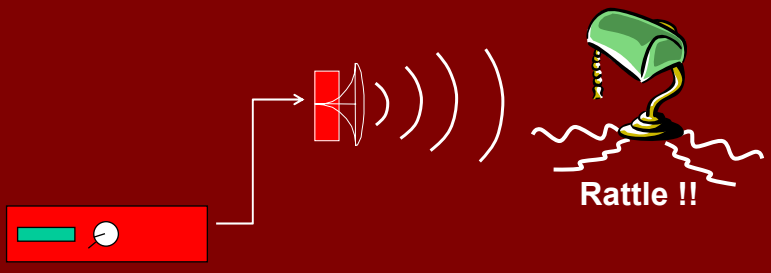
Background Noise Summary

- Background noise degrades dynamic range, detail clarity, and intelligibility
- Noise can be detected with test instruments or earplugs and ears
- Treatments include seals, better walls, slower air, quieter air handlers, etc.

Vibration Control

Rattles

Rattle Detection



Single Tone Oscillator –
Sweep slowly from
20 Hz to 1 kHz

Listen!
Look!
Fix It!

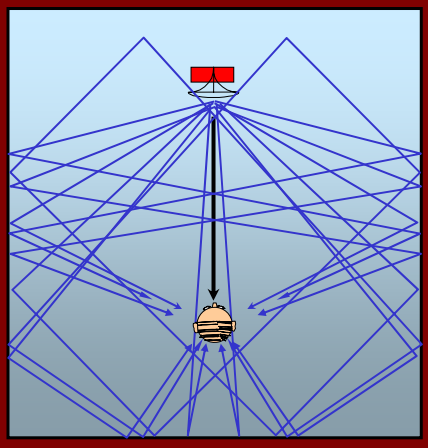
Rattles (continued)

- Method: use slow varying frequency sweep
- Check
  - Furniture
  - Glass Surfaces
  - Track Lights
  - Hung Pictures
  - Walls and Doors
  - Fixtures
  - HVAC Ducts and Vents
  - Ventilation System

Decay Time

Aka Reverberation

Reverberation

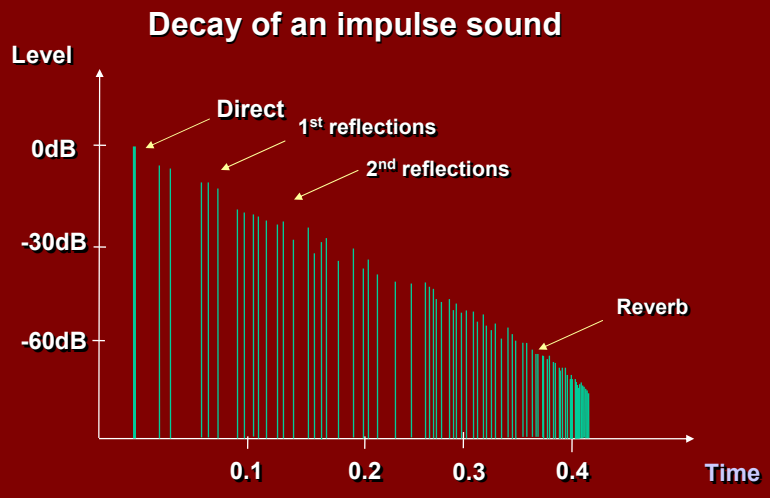


- Reverberation is the result of multiple reflections
- Decay time and spectrum have to be just right

Reverberation

- When the sound has bounced around the room several times
- No net direction or time cues remain
- Small room reflections die out before complete reverberation is achieved
- We call it decay time

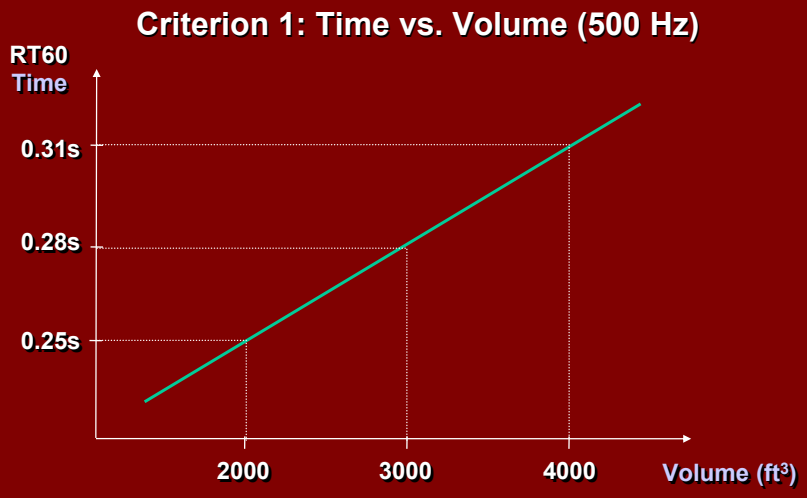
Decay Time



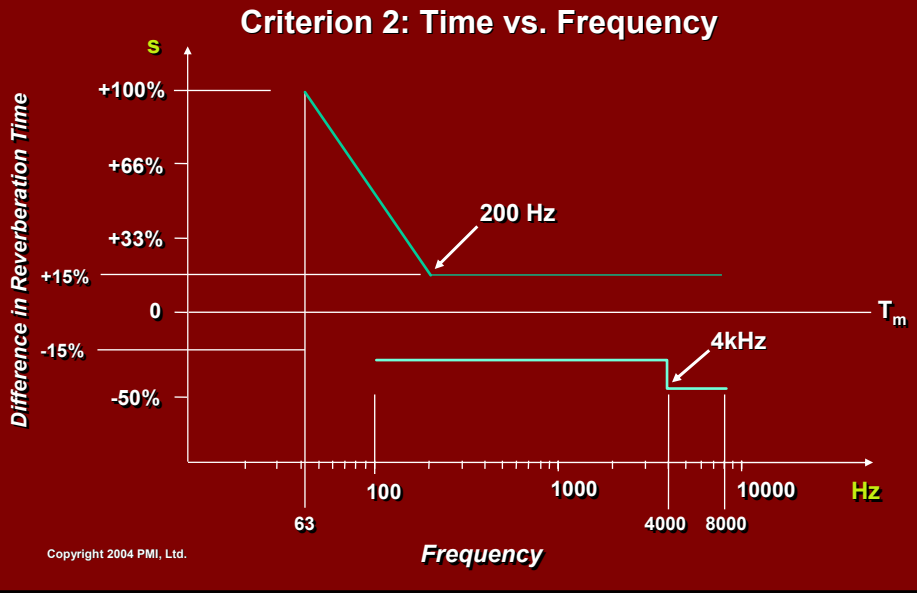
Decay Guidelines

- Decay time should be .2 to .4 seconds
- Research shows that most people like the same range of decay time
- $T_m = 0.3\ (V/3532)^{1/3}$ ±15% where V=room volume in ft^3
- $T_m = 0.3\ (V/100)^{1/3}$ ±15% where V = room volume in m^3
- Handy rule of thumb for project studios, look for ~25% absorptive wall area

Decay Time



Tolerance Limits for Decay Time



Decay Time
Getting it right

- Use the right amount of "frictional" absorption for the mids and highs
- Use the right amount of perforated panel bass absorption
- Calculate the amount with the Sabine, Eyring or Arau- Puchades equations
  - Know the absorption coefficient of materials
  - Be prepared to do lots of math

Decay Time
Getting it right

- The Sabine equation: Good but old

$$RT60 = \frac{0.049V}{S_{total}a}$$

V is volume
S is absorption surface area
a is absorption coefficient

- The Eyring equation: Better and more recent

$$RT60 = \frac{0.049V}{-S \ln(1-A)}$$

V is volume
S is total room surface area
A is area-weighted averaged absorption coefficient

Decay Time
Getting it right

- The Arau- Puchades equation: Best and latest

$$RT60 = \left[\frac{0.161V}{-S\ \ln(1-\bar{\alpha}_x)}\right]^{x/s} \times \left[\frac{0.161V}{-S\ \ln(1-\bar{\alpha}_y)}\right]^{y/s} \times \left[\frac{0.161V}{-S\ \ln(1-\bar{\alpha}_z)}\right]^{z/s}$$

V is volume
S is total room surface area
α is area-weighted averaged absorption coefficient for each wall
x is area of Left +Right walls
y is area of Front + Rear walls
z is area of Floor + Ceiling

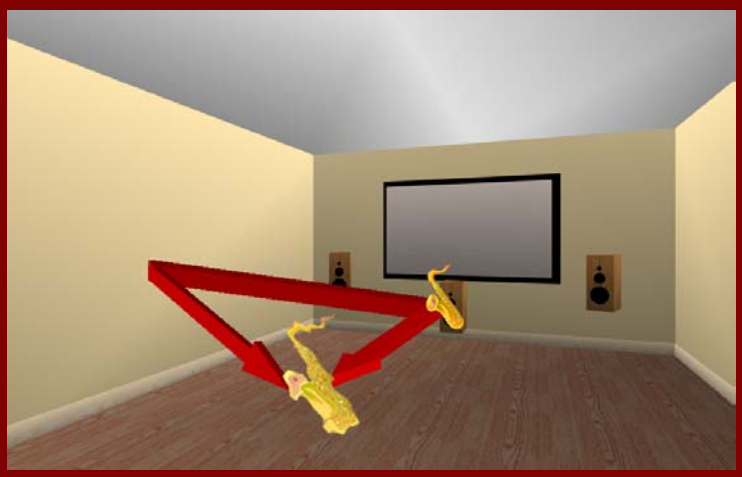
Decay Time
Getting it right

- Spread absorption materials around the room surfaces
- Also use diffusion to smooth out decay
- Diffusion enhances absorption effectiveness

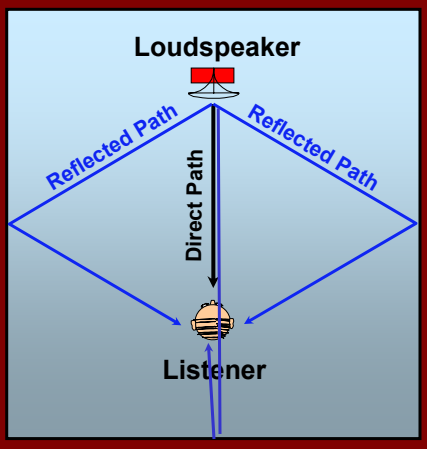
Placing Treatment Materials

Sound Reflections

Reflections = Distortion



Room Reflections



- Reflections cause
  - Blurring of image
  - Spectral imbalance by comb filtering

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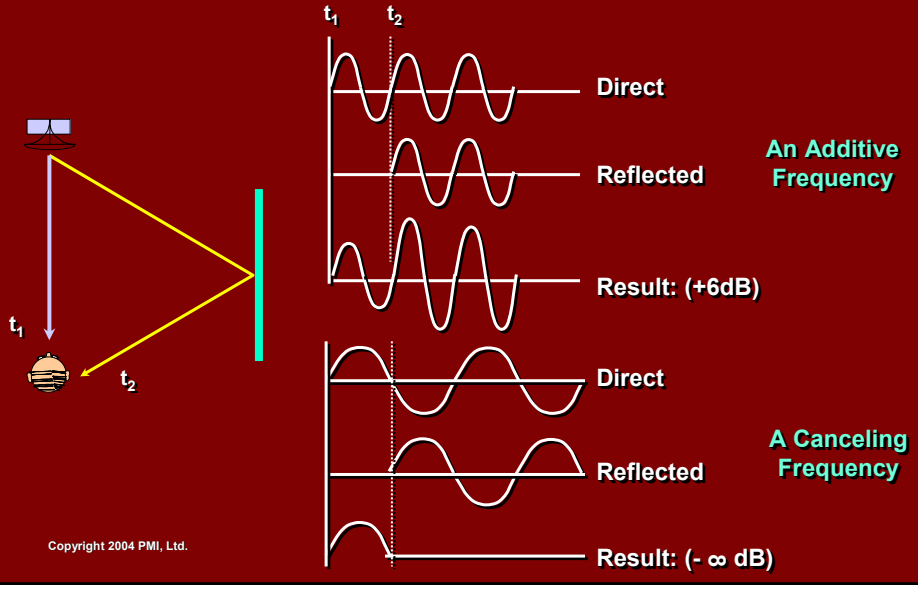
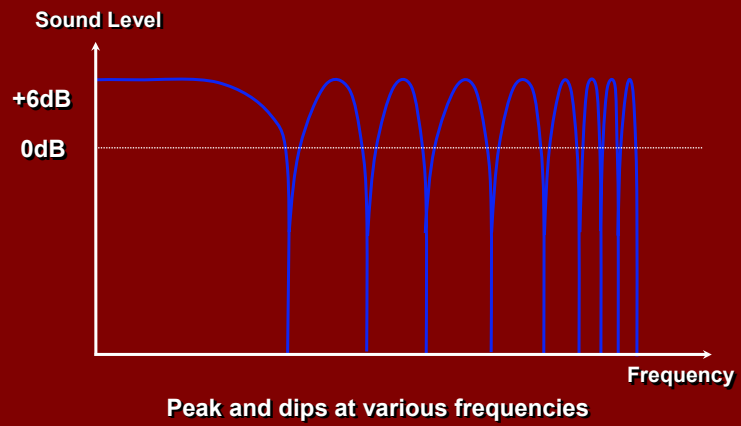
Room Reflections
Comb Filter Effect (Part 1)



Room Reflections
Comb Filter Effect (Part 2)

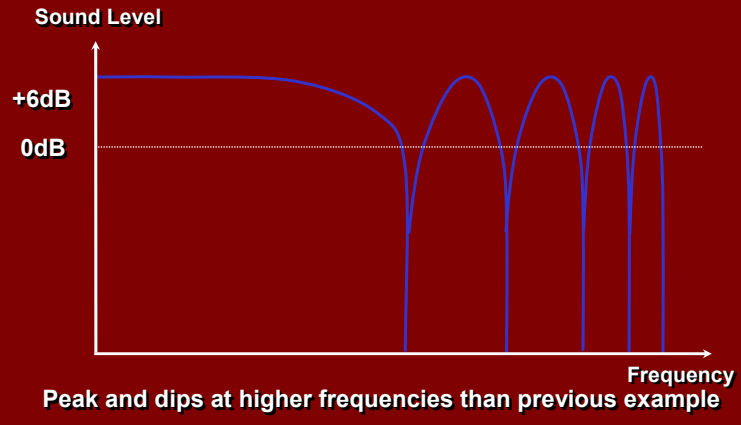
Resultant Frequency Response from Reflection



Peak and dips at various frequencies

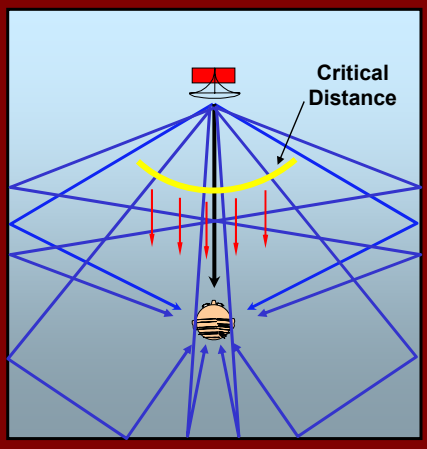
Room Reflections
Comb Filter Effect (Part 3)

Resultant Frequency Response from Shorter Reflection



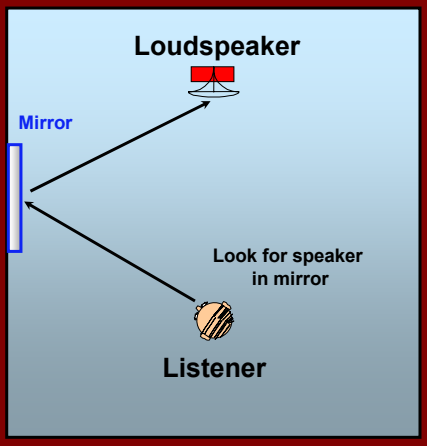
Peak and dips at higher frequencies than previous example

Room Reflections
Did you Know?!



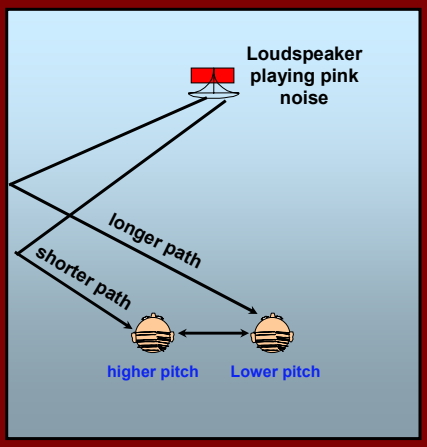
- At main seat you listen to more reflected sound than direct!
- "Critical Distance" is where direct sound and reflected sound energy are equal- about 4 feet in untreated rooms
- Need to move Critical Distance closer to listener

Room Reflections
Detection Methods



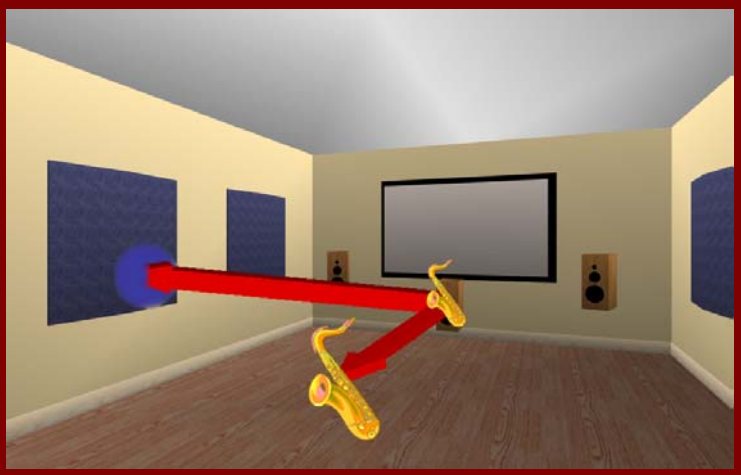
- Mirror
  - Move a mirror up and down side wall and find location where speaker is visible
  - This could be an offending reflection point

Room Reflections
Detection Methods (continued)

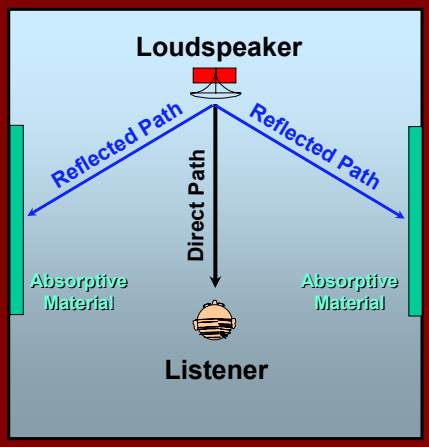


- Changing comb filters
  - Play pink noise from speaker
  - Move head location left-to-right
  - Listen for changing comb filters, or "phasiness"

Solutions to Room Reflections
Absorption



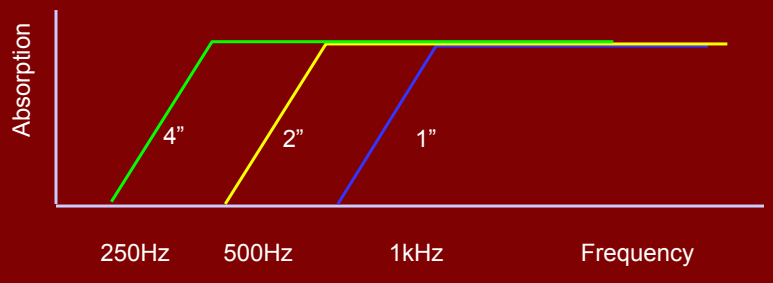
Solutions to Room Reflections
Absorption



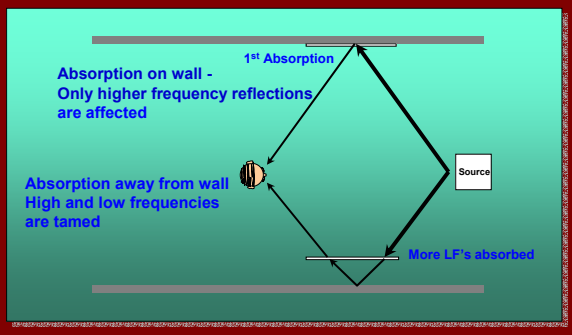
- Absorptive materials
  - Fiberglass
  - Dense foam
  - Draperies
  - Stuffed chairs
- "Scrub" off acoustic energy through friction
- Treat the ceiling too!

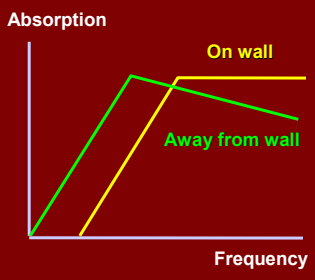
Acoustical Treatments
Absorption Thickness

- 1" Panels work down to 1kHz
- 2" Panels work down to 500Hz (better)
- 4" Panels work down to 250Hz (best)



"Floating" an Absorption Panel





Acoustical Treatments Notes on Absorption

- Don't "over absorb"
  - Dead rooms sound odd
  - Target sound reflection decay time: 0.3s
  - 25% coverage of wall surface

Acoustical Treatments
Notes on Draperies

- Draperies are uneven acoustical absorbers
- Performance affected by fabric weight, pleat number, distance from boundary
- At least 3” air gap
- Velour mass 32 ounces per lineal yard
- 100% fullness

Low Frequency Reflections

Placing Speakers

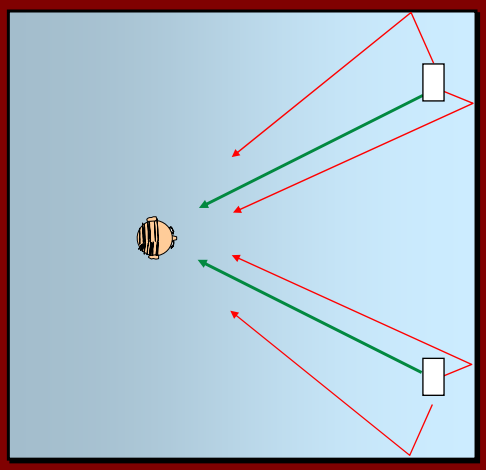
Boundary Effects
Loudspeaker/ Room Interactions

- Reflection issues at low frequencies are called “boundary effects”
- Peaks and dips in bass/mid frequencies depend on speaker location
- Low frequencies are hard to absorb

Low Frequency Reflections Strategies

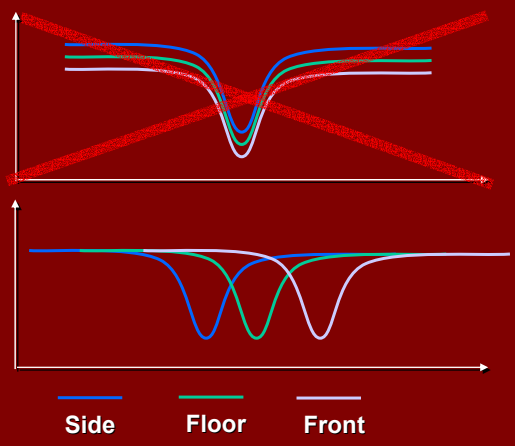
- First reduce peak/dip errors through proper placement
- “Resistive” Absorbers too thick
- Use Helmholtz and Diaphragm methods
- Equalize

Front Speaker Placement Unequal Boundaries



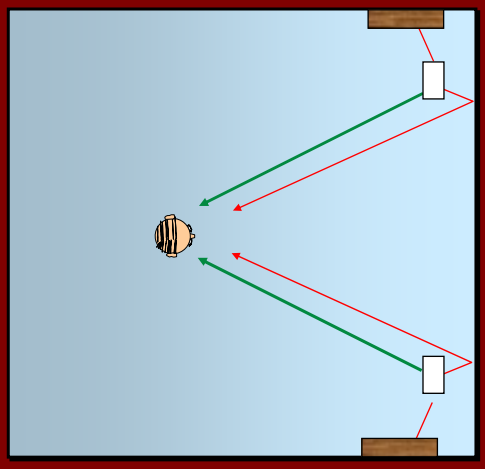
Unequal Reflected Path Lengths

Front Speaker Placement (continued)



- Aim for unequal reflection path lengths for floor / side / front wall
- Distribute errors

Solutions to LF Reflections
Bass Absorption

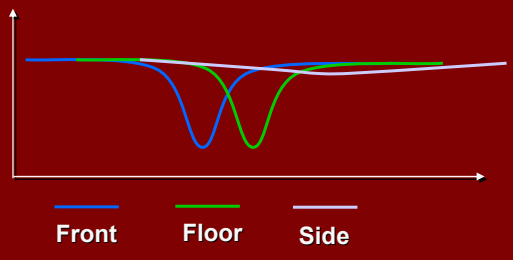


- Use Perforated wood surface on box
- Tuning equation:

$$f_0 = 200\sqrt{\frac{p}{(d)\,(t)}}$$

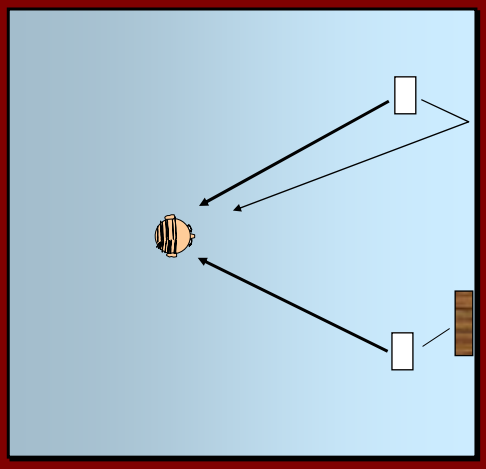
f_0 is frequency
p is perforation percentage
t is hole length
d is air space depth

Solutions to LF Reflections
Bass Absorption



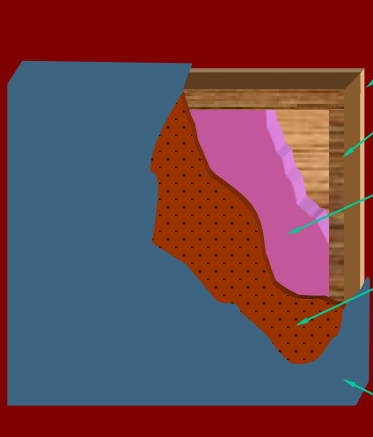
- With Bass absorber, Side wall response is smoother
- The remaining error can be equalized
- Can also use Bass absorbers on front wall

Solutions to LF Reflections
Bass Absorption on the front wall



- Use Bass absorber to kill front wall reflection

Solutions to LF Reflections
A Bass Absorber



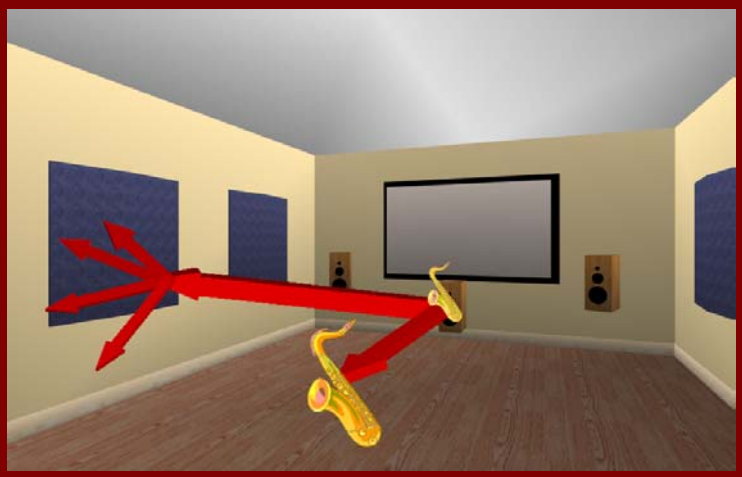
Boundary Effects

- Evaluation
  - Computer predictions
    - CARA
    - RPG Room optimizer
  - Use circulating pink noise and listen for timbral variations
  - Use pink noise and RTA to measure spectral variations
- Correction
  - Avoid multiple equal boundary distances
  - Change speaker position
  - Match boundary conditions for the front speakers
  - Flush mount speakers
  - Use low frequency absorption
  - Equalize

Reflection Control

Diffusion

Solutions to Room Reflections
Diffusion



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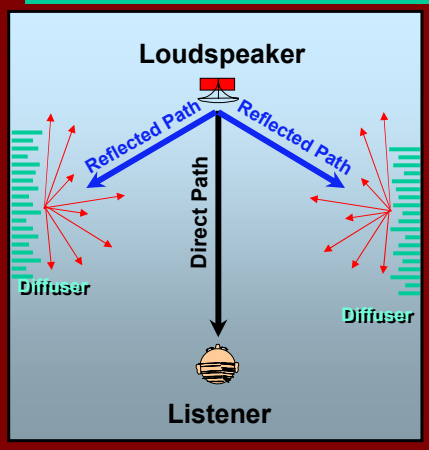
Solutions to Room Reflections
Diffusion



- Diffusive materials
  - Purpose bilt panels
  - Bookcase

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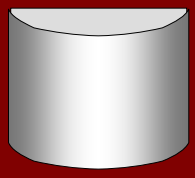
Acoustical Treatments
Diffusion

- Need enough diffusion surface to "smooth out" the soundfield
- Balance diffusion and absorption
- Keep some liveness to the room

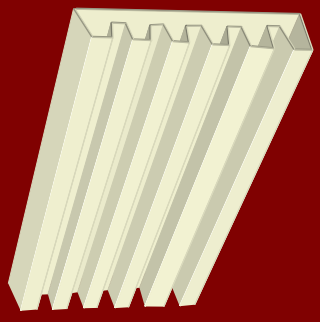
Acoustical Treatments
Diffusion types

- 2D diffusion redistributes incident sound to a plane
  - Use along front portion if side walls to diffuse front speakers
- 3D diffusion redistributes sound to a hemisphere
  - Use it towards the rear of room for surround speakers

Acoustical Treatments
Diffusion – 2D Diffusers



Cylindrical



Slotted

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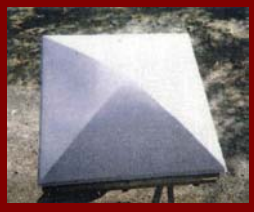
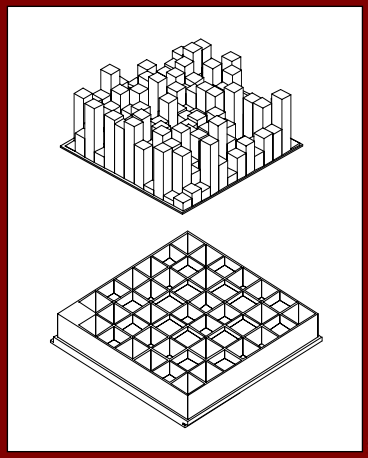
Acoustical Treatments
Diffusion - 3D Diffusers





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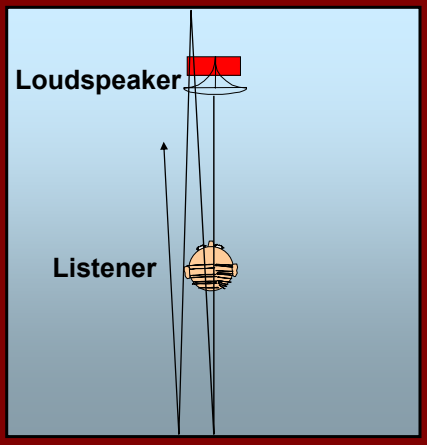
Acoustic Treatment Manufacturers

- StudioPanel
- RPG
- Acoustics First
- Kinetics Noise Control
- Auralex
- And many others!

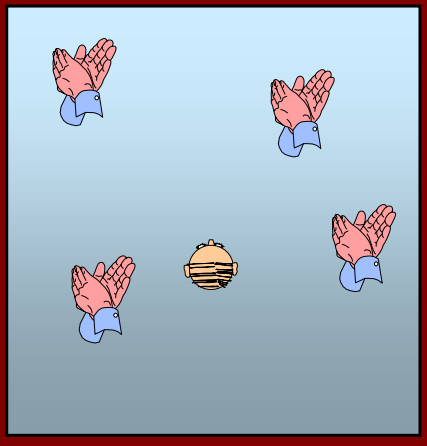
Slap Echoes

Slap Echoes



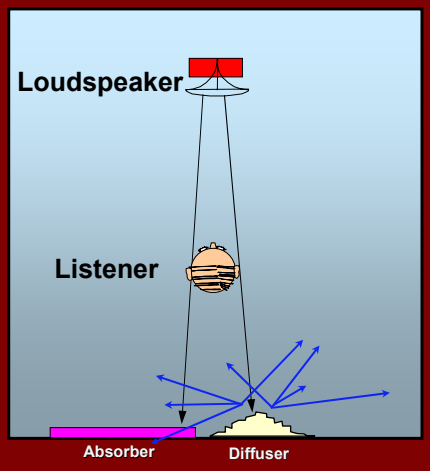
- Echoes are
  - Repeated reflections between two parallel surfaces
- Slap echoes cause
  - Bright, “zingy” sound
  - Interference with acoustic character of sound
  - Timbral changes

Slap Echoes
Detection Methods



- Clap hands at various locations in room
- Listen for echo
- If possible, sit at primary seat and listen to a person clapping at various locations

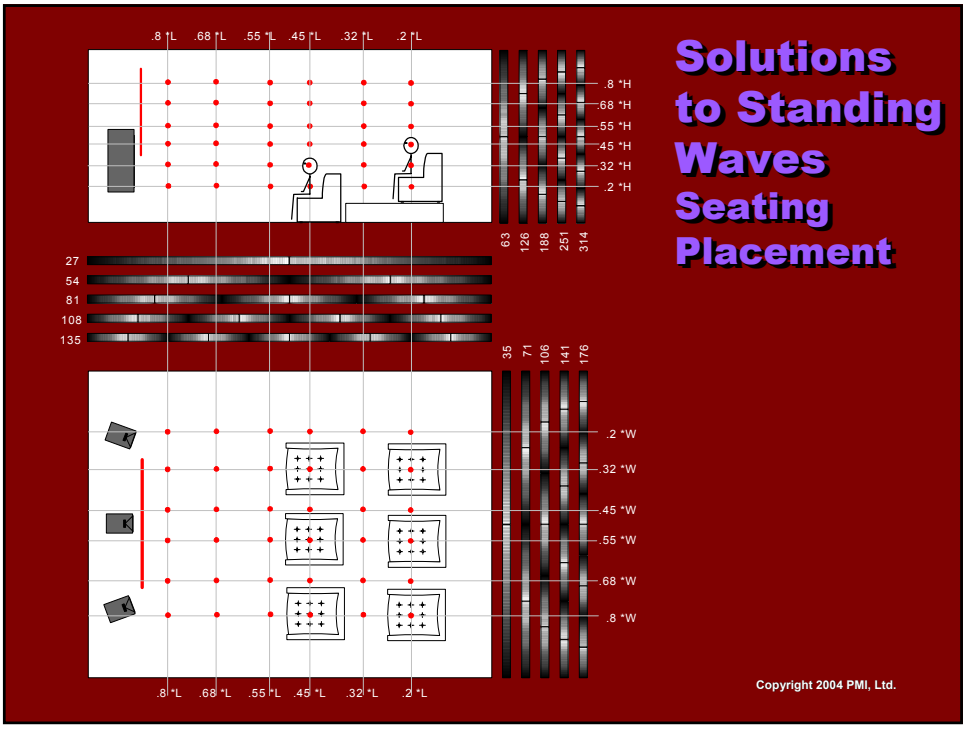
Solutions to Echoes
Materials

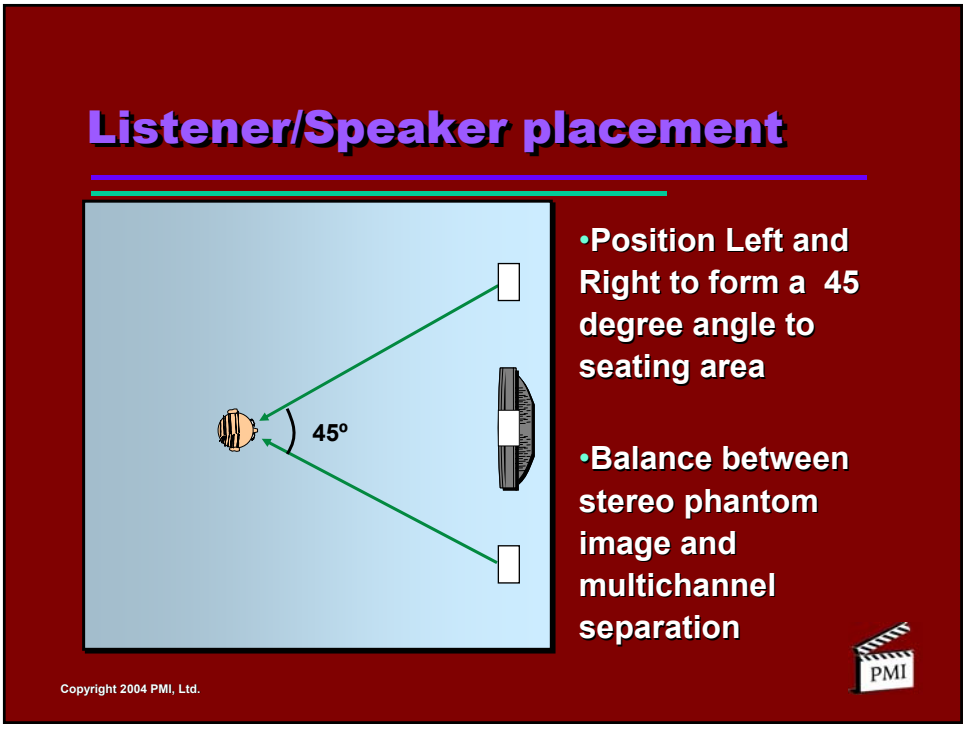


- Absorptive
  - Fiberglass panels
  - Foam panels
  - Drapes
- Diffusive
  - Diffuser panels
  - Bookcases
  - Furniture

Placing listeners

Don’t sit at resonance peaks or dips


Solutions to Standing Waves
Seating Placement
.8 *L
.68 *L
.55 *L
.45 *L
.32 *L
.2 *L
.8 *H
.68 *H
.55 *H
.45 *H
.32 *H
.2 *H
63
126
188
251
314
27
54
81
108
135
35
71
106
141
176
.2 *W
.32 *W
.45 *W
.55 *W
.68 *W
.8 *W
Copyright 2004 PMI, Ltd.


Listener/Speaker placement
45º
•Position Left and Right to form a 45 degree angle to seating area
•Balance between stereo phantom image and multichannel separation
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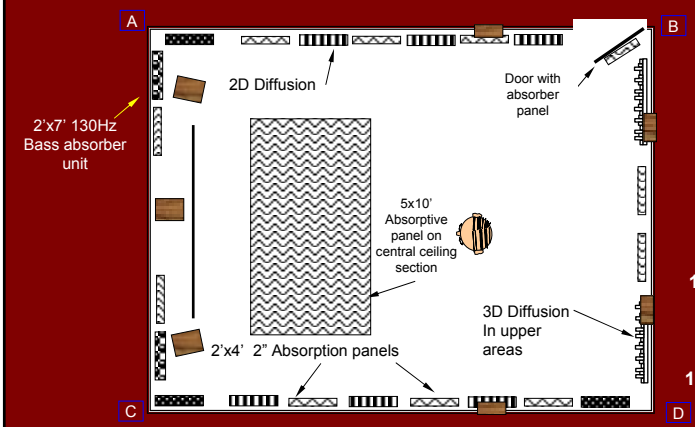
Example Layout

Example Treatment Layout



CinePanel 2D Diffuser

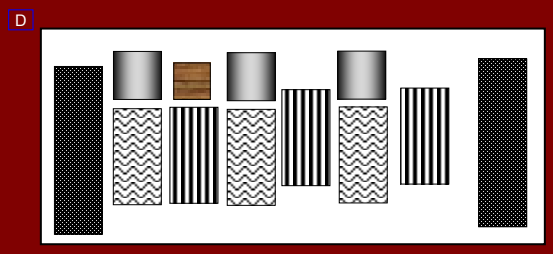
3D Diffuser

Absorption CinePanel

107Hz Bass absorption units

130Hz Bass absorption units

Example Treatment Layout
Left Wall



Surround speaker

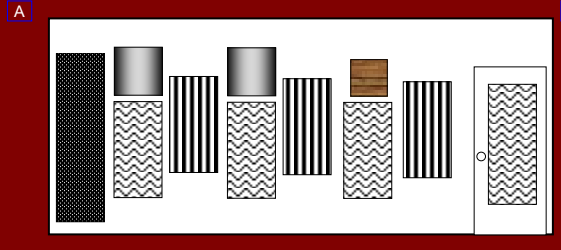
Cylindrical Diffuser
Acoustic Innovations 2ftx2ft

CinePanel Diffuseur
2ftx4ft

CinePanel Absorber
2ftx4ft

107Hz Diaphragmatic Absorber
2ftx5ft

Example Treatment Layout
Right Wall



Surround speaker

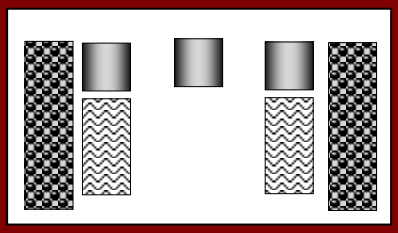
Cylindrical Diffuser
Acoustic Innovations 2ftx2ft

CinePanel Diffuseur
2ftx4ft

CinePanel Absorber
2ftx4ft

107Hz Diaphragmatic Absorber
2ftx5ft

Example Treatment Layout
Front Wall

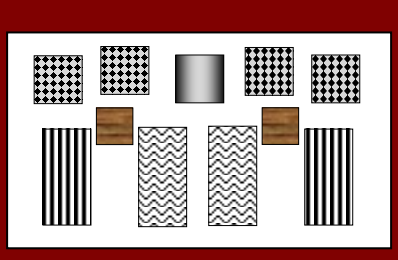


Cylindrical Diffuser
Acoustic Innovations 2ftx2ft

CinePanel Absorber
2ftx4ft

130Hz Diaphragmatic Absorber
2ftx5ft

Example Treatment Layout
Rear Wall



Rear speaker

Cylindrical Diffuser
Acoustic Innovations 2ftx2ft

CinePanel Absorber
2ftx4ft

CinePanel Diffuseur
2ftx4ft

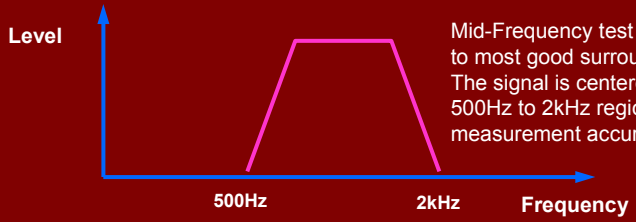
3D Diffuser
Acoustic Innovations 2ftx2ft

Tuning it All

Analysis and equalization

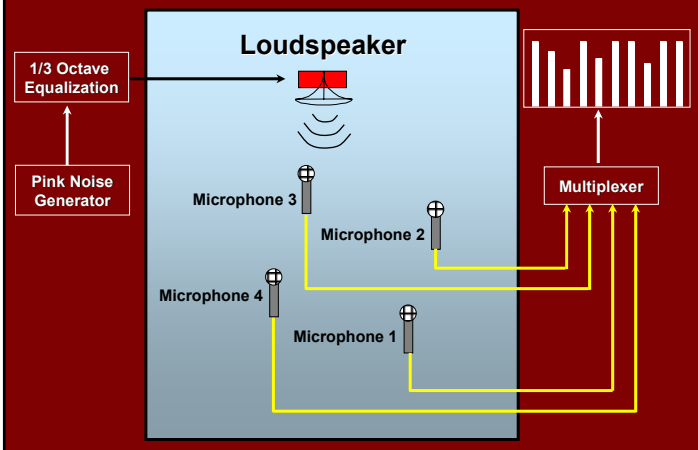
Level Calibration

- Use midband pink noise signals
  - reference disk or internal test tones



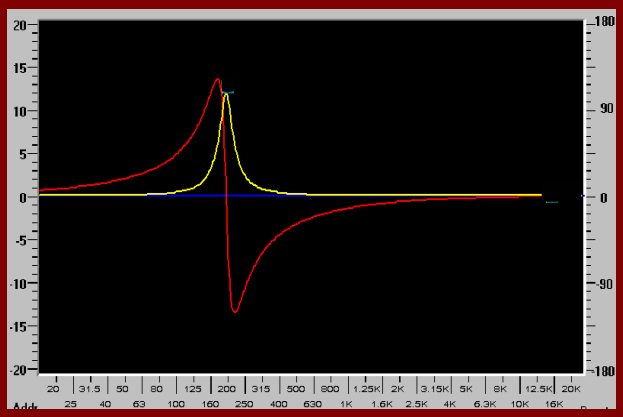
Mid-Frequency test noise internal to most good surround processors. The signal is centered in the 500Hz to 2kHz region to improve measurement accuracy

Analysis – the useful way



- Analysis should be spatially and temporally averaged
- Use Gold Line DSP30 Analyzer, or equivalent

Frequency Response Calibration
Room + Equalizer Phase Response



- 12 dB peak error at 200 Hz (yellow line)
- Phase error (red line)
- Equal cut introduces inverse phase error
- Amplitude and phase are corrected!

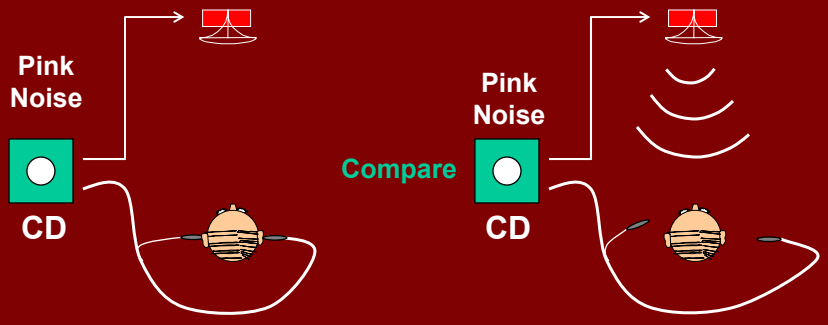
Equalization Requirements

- Pink noise source
  - 20 Hz–20 kHz, switchable to each channel before the crossover (5.1 Audio Toolkit)
- Real time analyzer
  - 20 second time averaging
  - The ability to average 4 or more readings from mic multiplexing
  - 1/12 octave resolution in low frequencies

PMI

Quick Check of Overall Frequency Response

Using Etymotic ER 4S or ER Œarphones

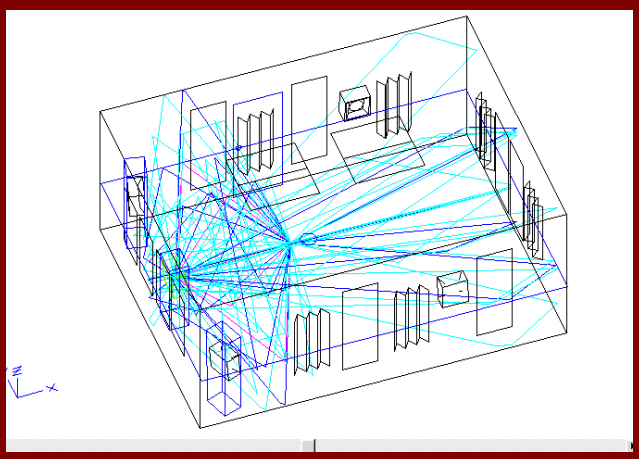


Set earphone level to match speaker

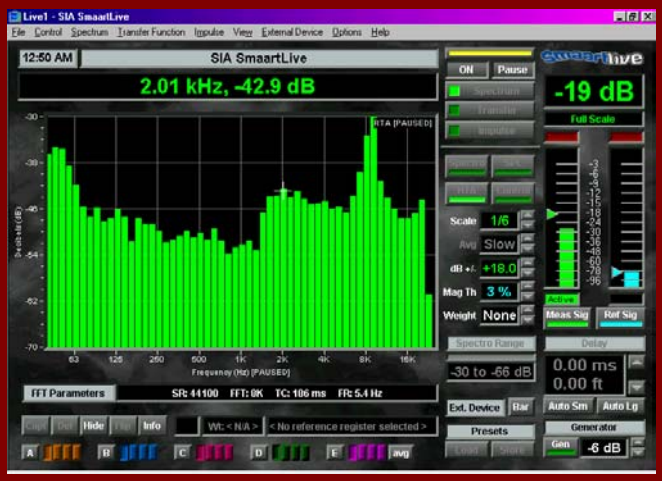
PMI

Tools

Ulysses



SMAART Live



Gold Line DSP30

- RTA
- 1/3, 1/6, 1/12th Octave
- Averaging
- NC
- RT60
- Integrated solution

TEF 2000

- RTA
- TEF
- MLSSA
- Log sweeps
- Phase measurements
- Many more

Good Reading Materials

- Acoustics and Psychoacoustics, Howard, David M., Angus, James, Focal Press, 1996, ISBN 0 240 51482 9
- Audio Engineering Handbook, Benson, K. Blair ed. McGraw-Hill Book Company, 1988
- Building a Recording Studio, Cooper, Jeff, Synergy Group, Inc., Los Angeles. To order call 1-800-468-4322
- The Master Handbook of Acoustics, Everest, F. Alton, TAB Books, Division of McGraw-Hill Inc., Blue Ridge Summit, PA. To order call 1-800-468-4322
- Project Studios, P. Newell, Focal Press, ISBN 0 240 51573 0
- Room Acoustics, Kuttruff, Heinrich, Applied Science Publishers 1973/1991

Summary

- Room acoustics affect any audio system
- Look out for reflections, echoes, boundaries, reverberation, standing waves, rattles, noise, and sound isolation
- With basic science and care you too can tame room acoustics.
- Thanks for listening,

Anthony Grimani

Contact Info

Anthony Grimani
PMI, Ltd
9A Mono Avenue
Fairfax, CA 94930
info@pmiltd.com
415 454 2087
www.pmiltd.com