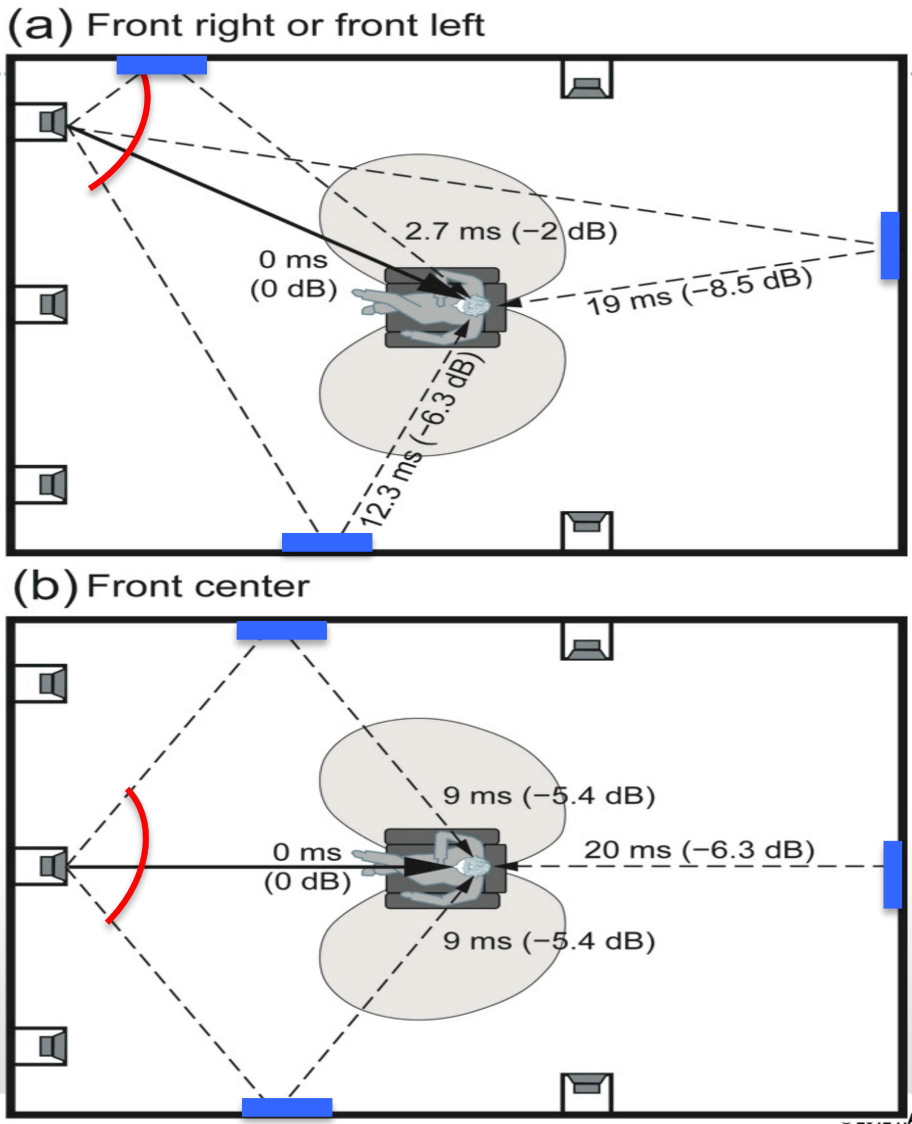
HARMAN

Basic Acoustic, Speaker Placement, and Installation Presentation

AKG harman/kardon Infinity JBL lexicon mark levinson



Most of what we hear and measure in a room is reflected sound

This means that the far-off-axis performance of loudspeakers is important.

It also means that the acoustical properties of the reflecting surfaces determine what is heard and measured.

Audio Facts

A good sounding loudspeaker is one that exhibits similarly **good on- and off-axis frequency responses**.

This excellence can only be heard if the reflections of this sound are spectrally similar to the direct sound.

So . . . if we want to modify reflections, we must attenuate (absorb) or scatter (diffuse) all frequencies above about 300 Hz in a similar manner.

Requirements for Acoustical Devices

- Absorbers need to be at least 3−4 inches (7.5–10 cm) deep and
- Scattering surfaces (a.k.a. diffusers) must be even thicker: about 8 inches (20 cm) for engineered surfaces and 12 inches (30 cm) for simple geometric shapes
- This will be difficult in the real world, but try to get as close to these requirements as possible.

Audio Folklore

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TRUE ✔ or FALSE ✖

Acoustical treatment begins with the elimination of all first reflections.

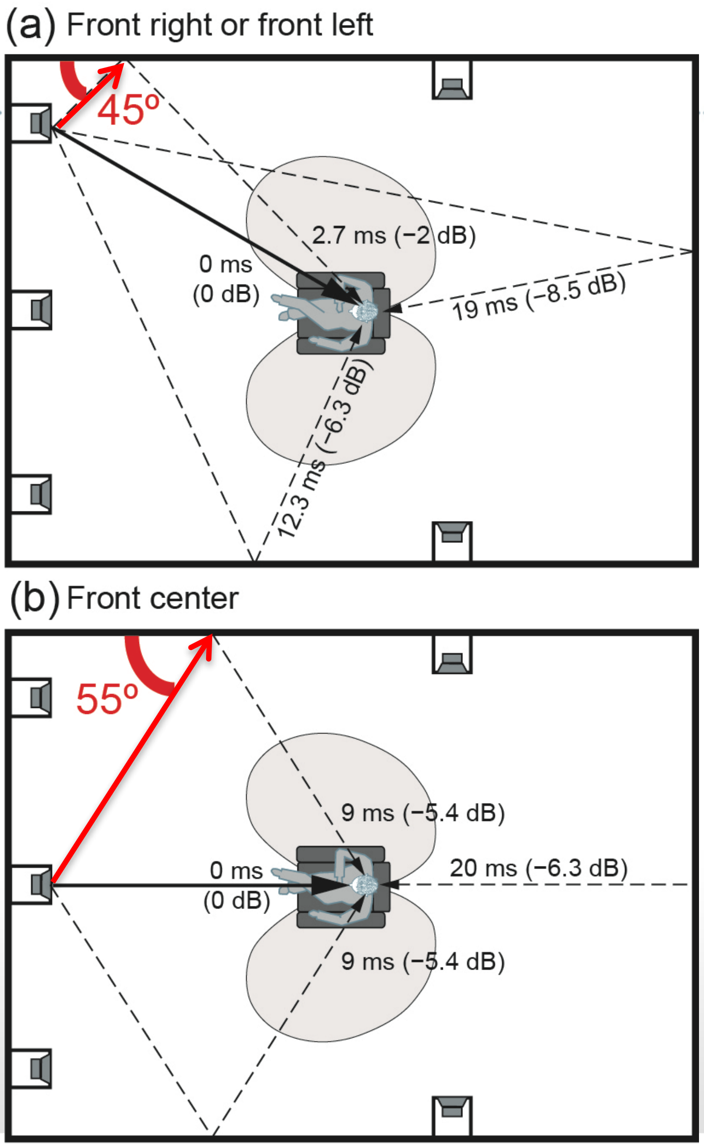
FALSE: If you do this the room will be unpleasantly “dead”. A certain amount of reflected sound is expected by two ears and a brain.

Remember: if you eliminate a first reflection, the second loudest sound arriving at the listener, you also eliminate all subsequent reflections that would have happened.

The room becomes more “dead” than might be desirable.

Room acoustics demystified

- Well-furnished normal living spaces (heavy carpet, sofa, chairs, drapes, bookcases and cabinets) meet the <0.5 s RT requirement and can be excellent listening environments.
- Measure the RT using the front center loudspeaker – this is the one that delivers the dialog. Listen for strong reflections from the rear wall! If there, absorb them.
- Custom home theaters need to be artificially "furnished".
- Because it is a "designed" space, there is no excuse for delivering less than excellent performance.



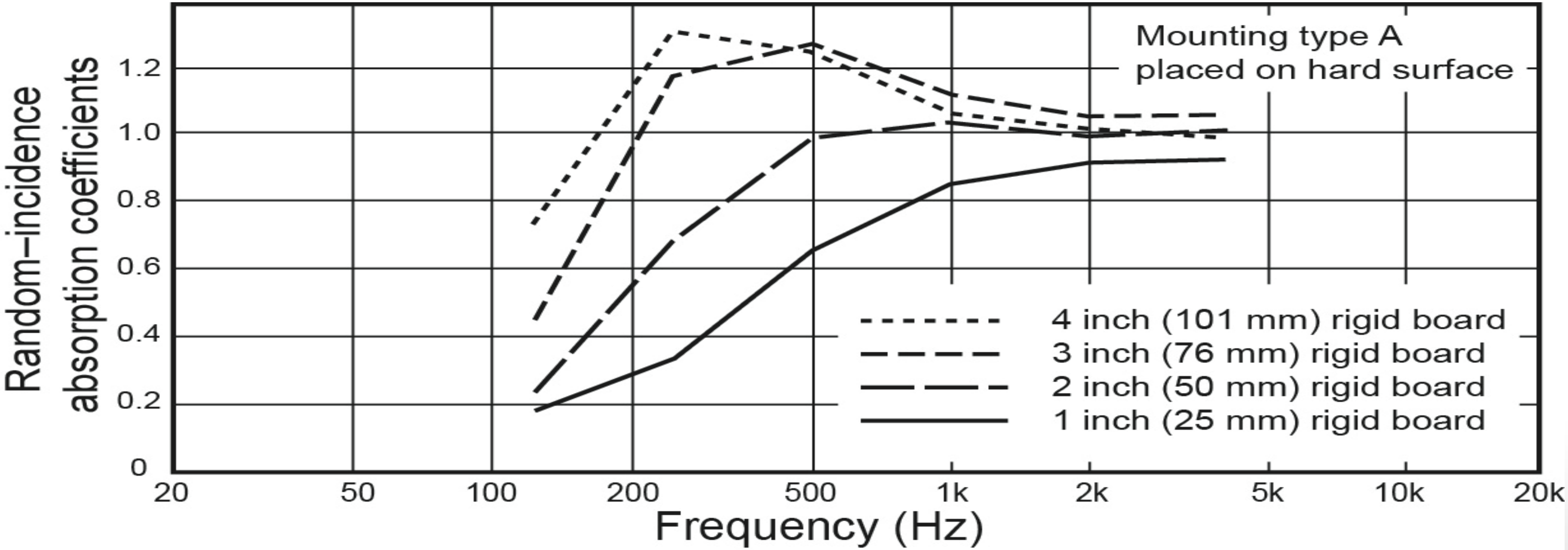
Looking at sidewall reflections:

The incident angles are well defined (good).

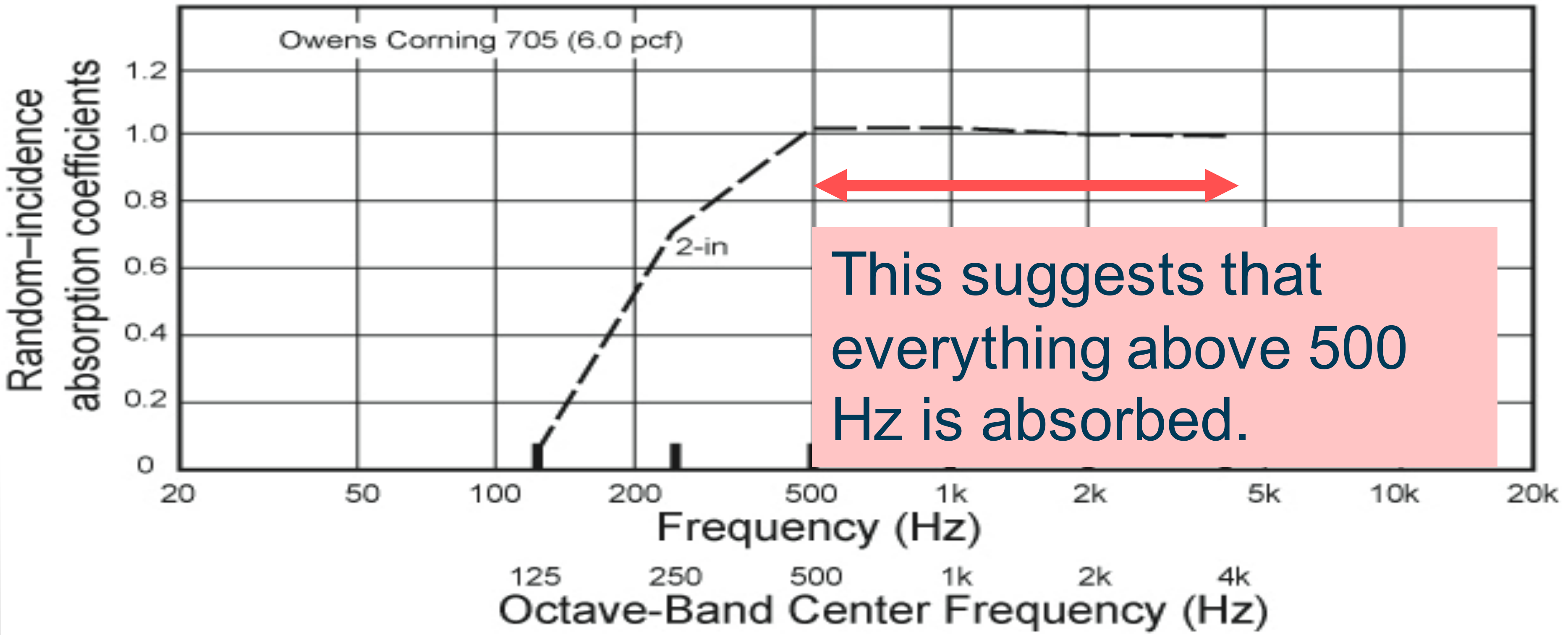
The absorption coefficients of materials we put on the walls are not specified for those angles (bad).

What really happens?

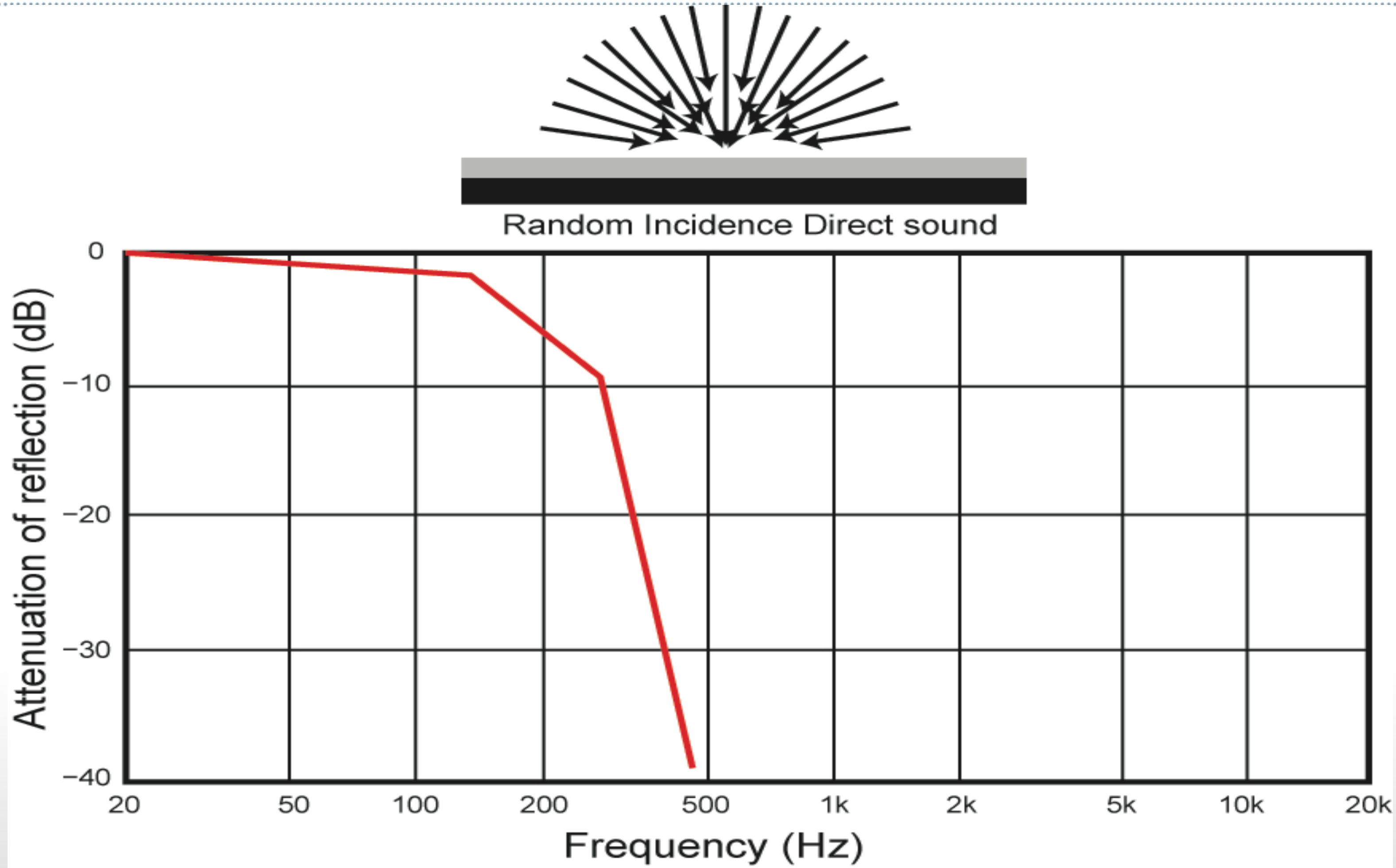
Traditional measures of absorption assume that sounds arrive from all possible angles simultaneously: i.e. "random incidence". OK for live concert halls but not useful for home theaters.



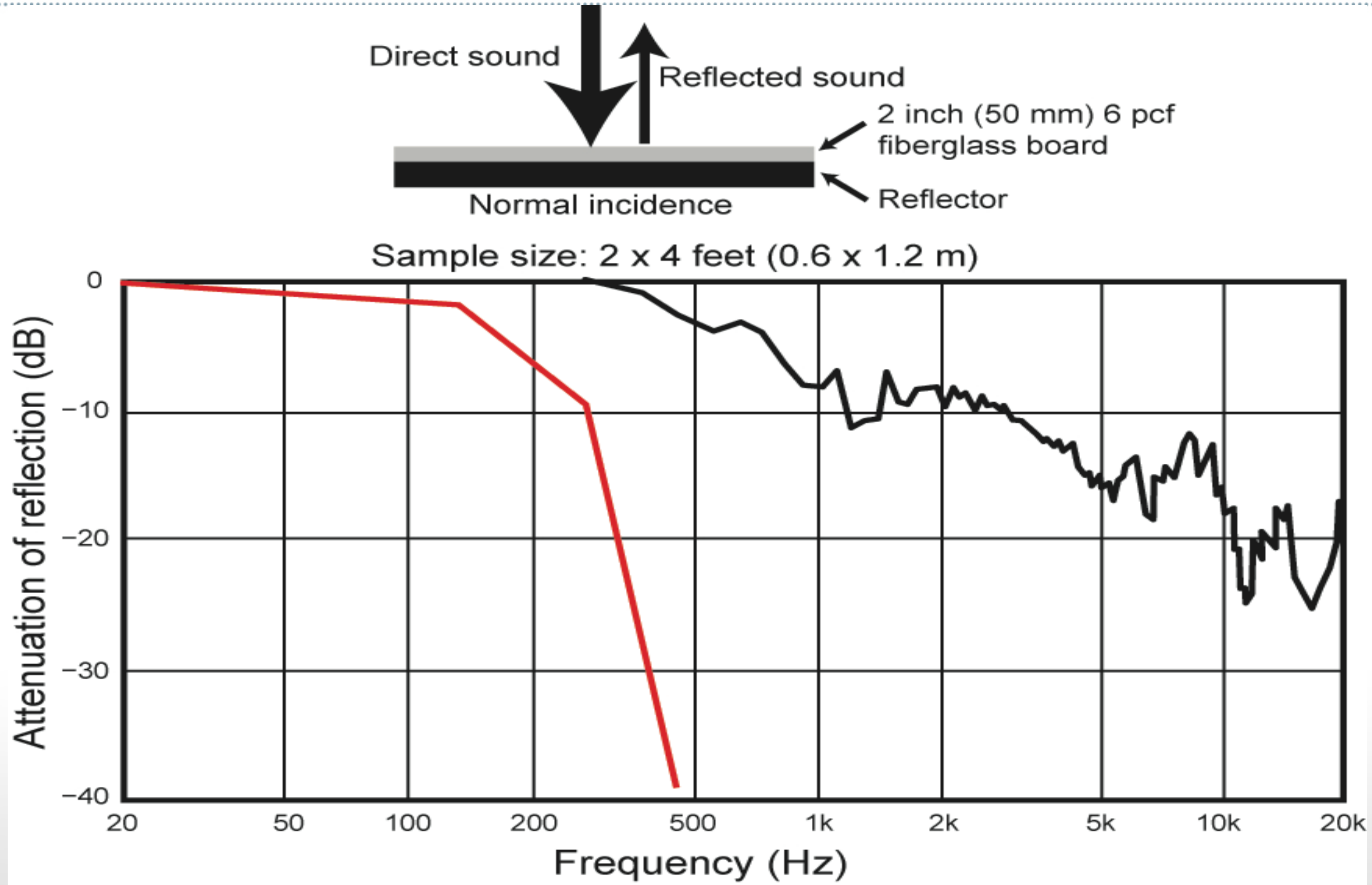
2-inch (50 mm) rigid fiberglass board



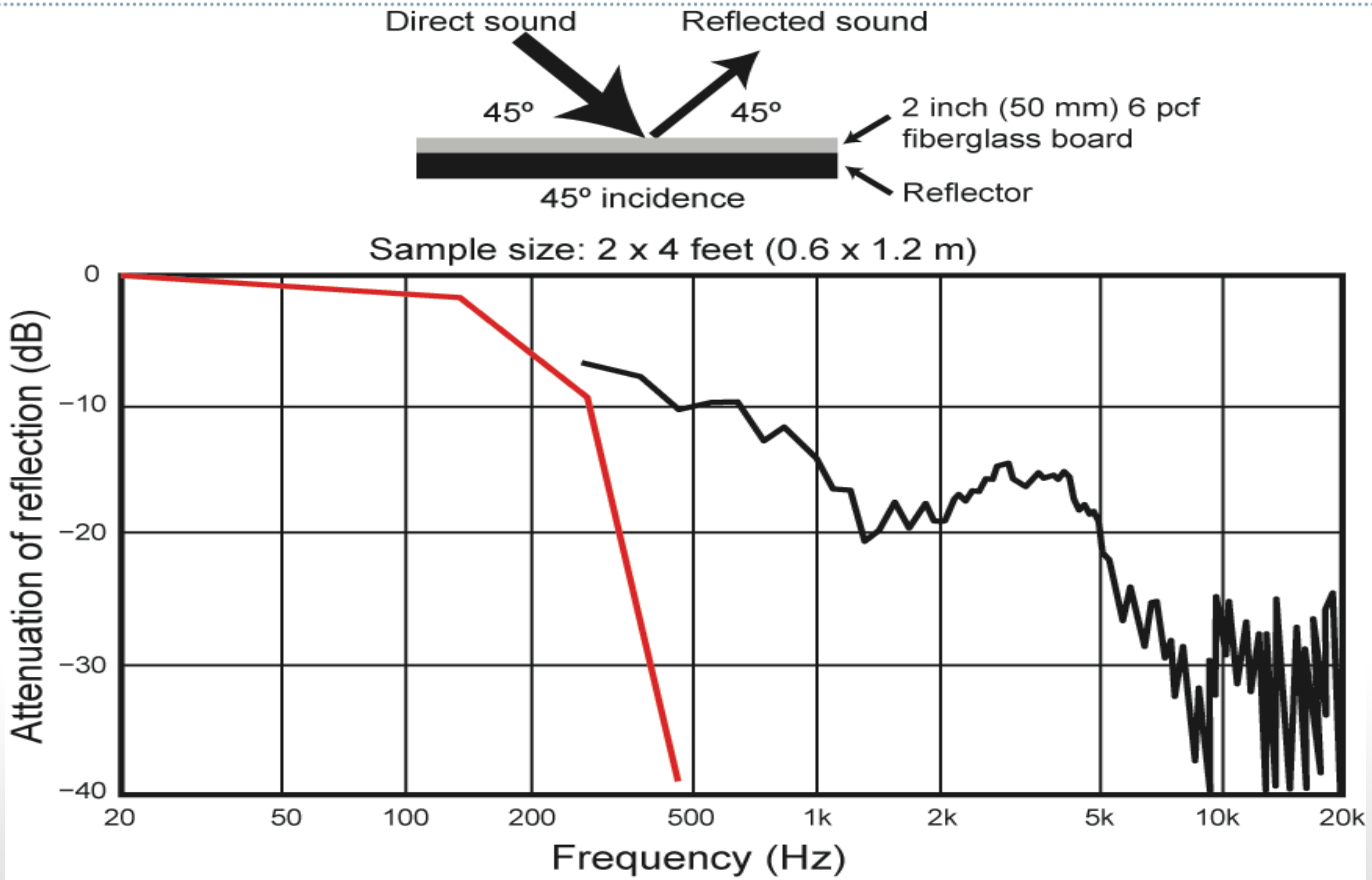
Attenuation of reflection at random incidence



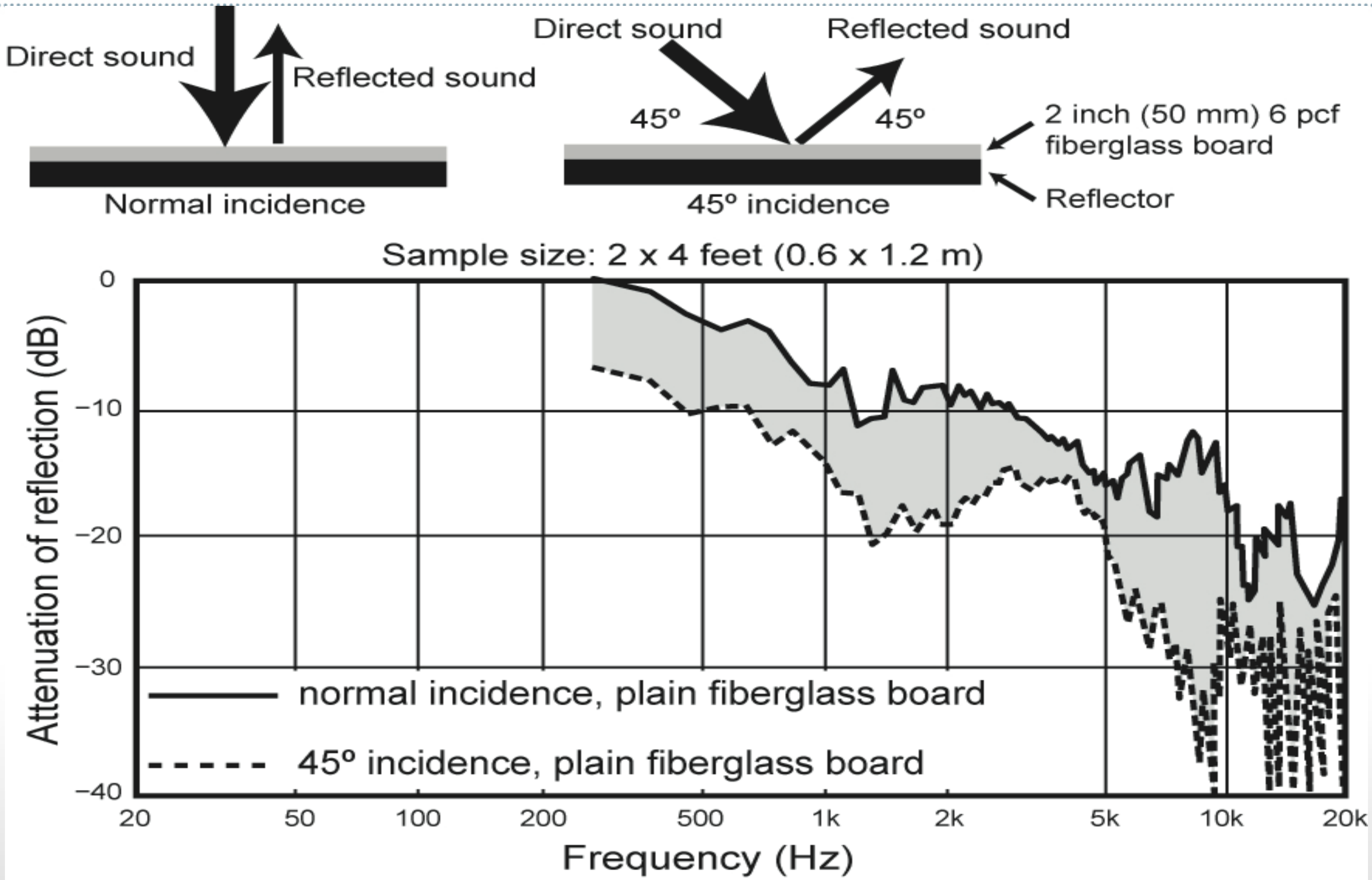
Attenuation of reflection at 0° incidence



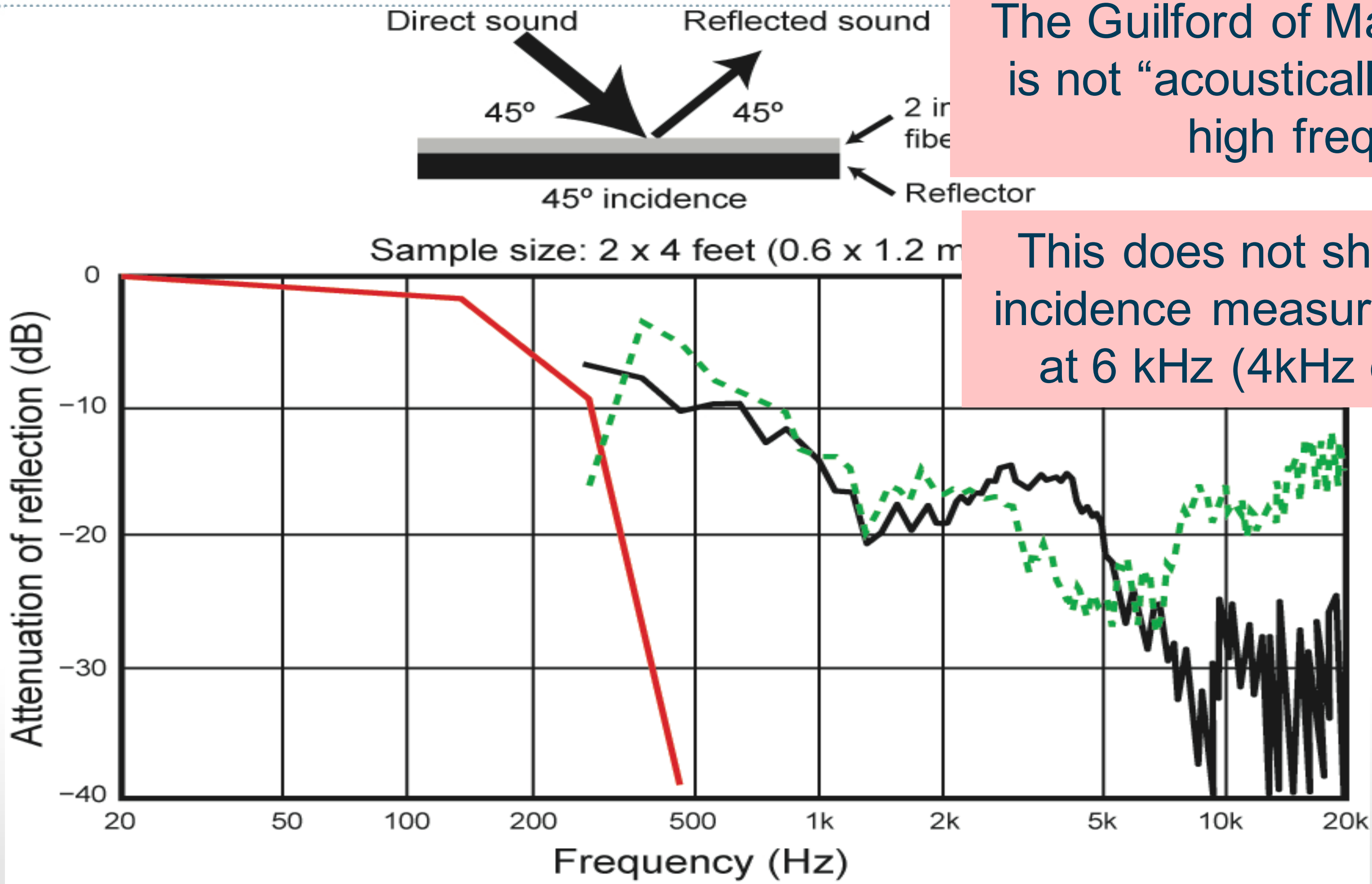
Attenuation of reflection at 45° incidence



Attenuation of reflection at 0° and 45° incidence



Attenuation of reflection at 45° incidence with fabric cover



The Guilford of Maine FR701 fabric is not “acoustically transparent” at high frequencies.

This does not show up in random-incidence measurements - they stop at 6 kHz (4kHz octave band CF)

A wall is an acoustic mirror, creating a duplicate loudspeaker

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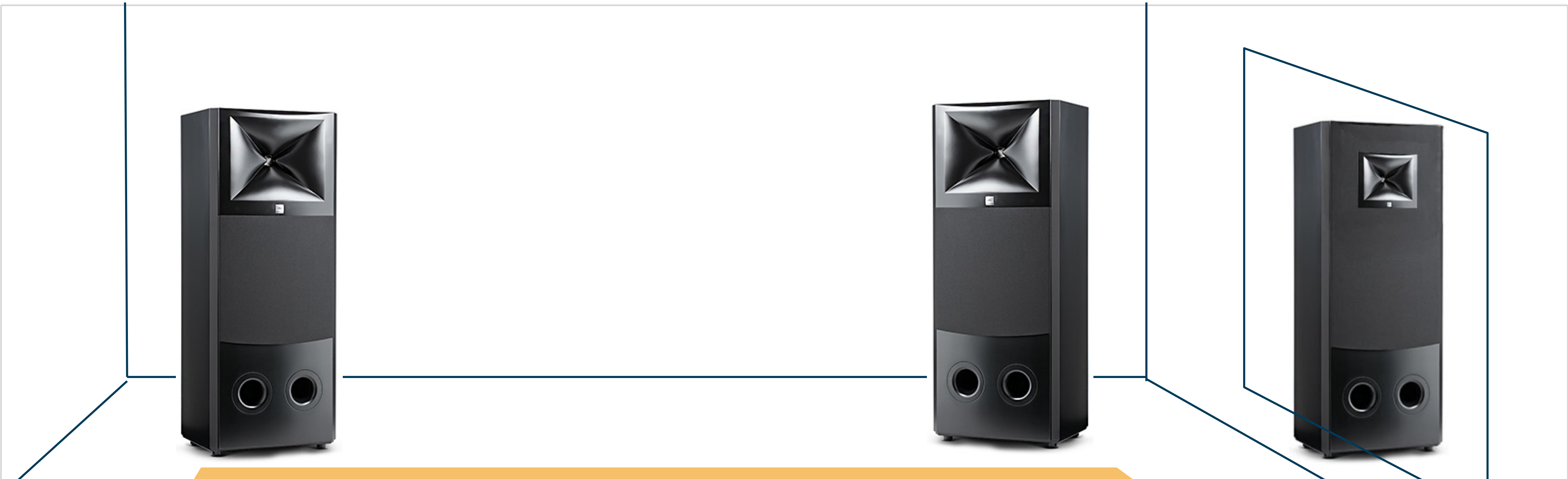
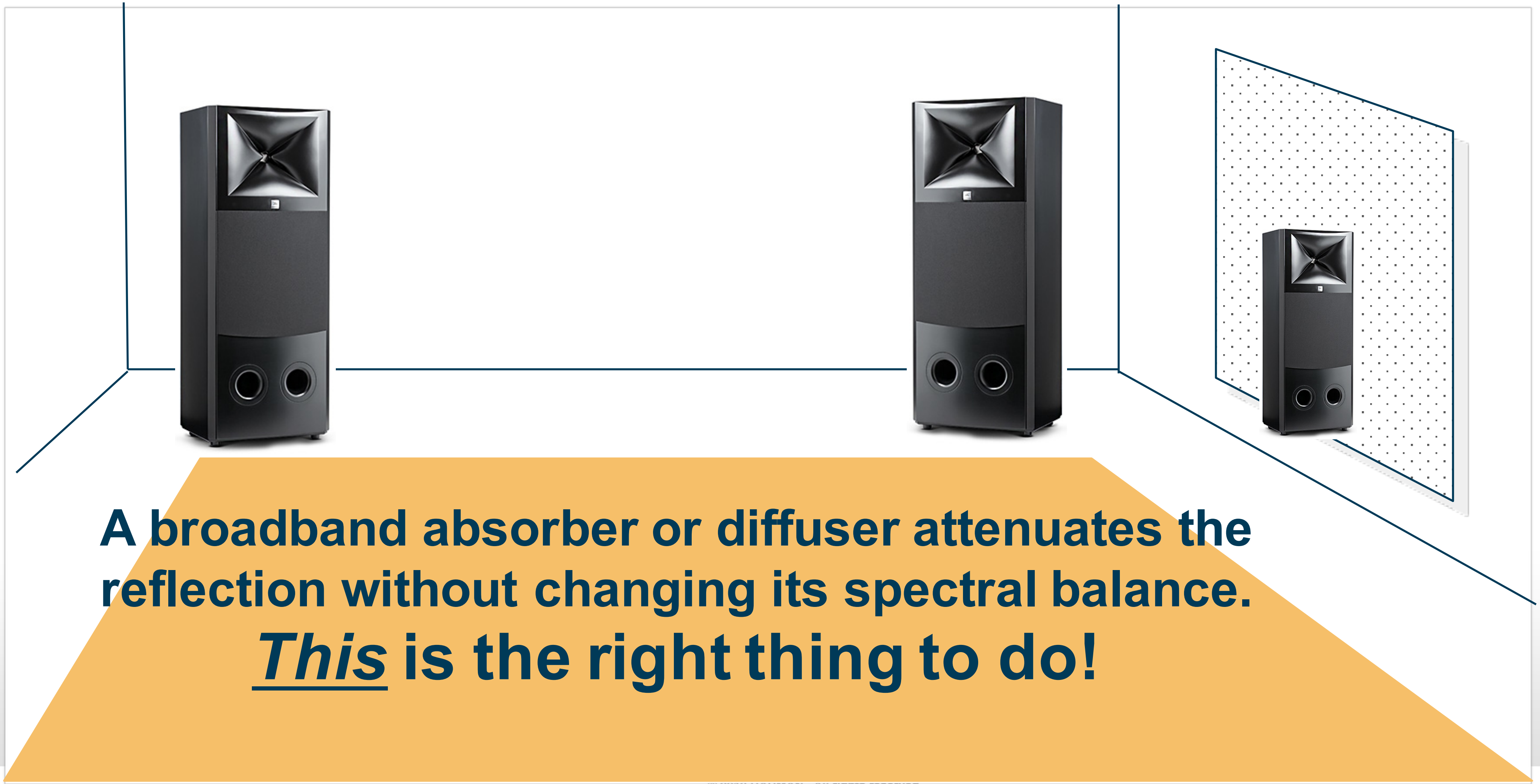
Put a 2-inch (50 mm) thick resistive
absorber at the reflection point



A 2” absorber redesigns the loudspeaker by attenuating the off-axis middle and high frequencies. The rest of the sound is still reflected, and the loudspeaker sounds duller.

This is not a good idea!



A broadband absorber or diffuser attenuates the reflection without changing its spectral balance.

***<u>This</u>* is the right thing to do!**

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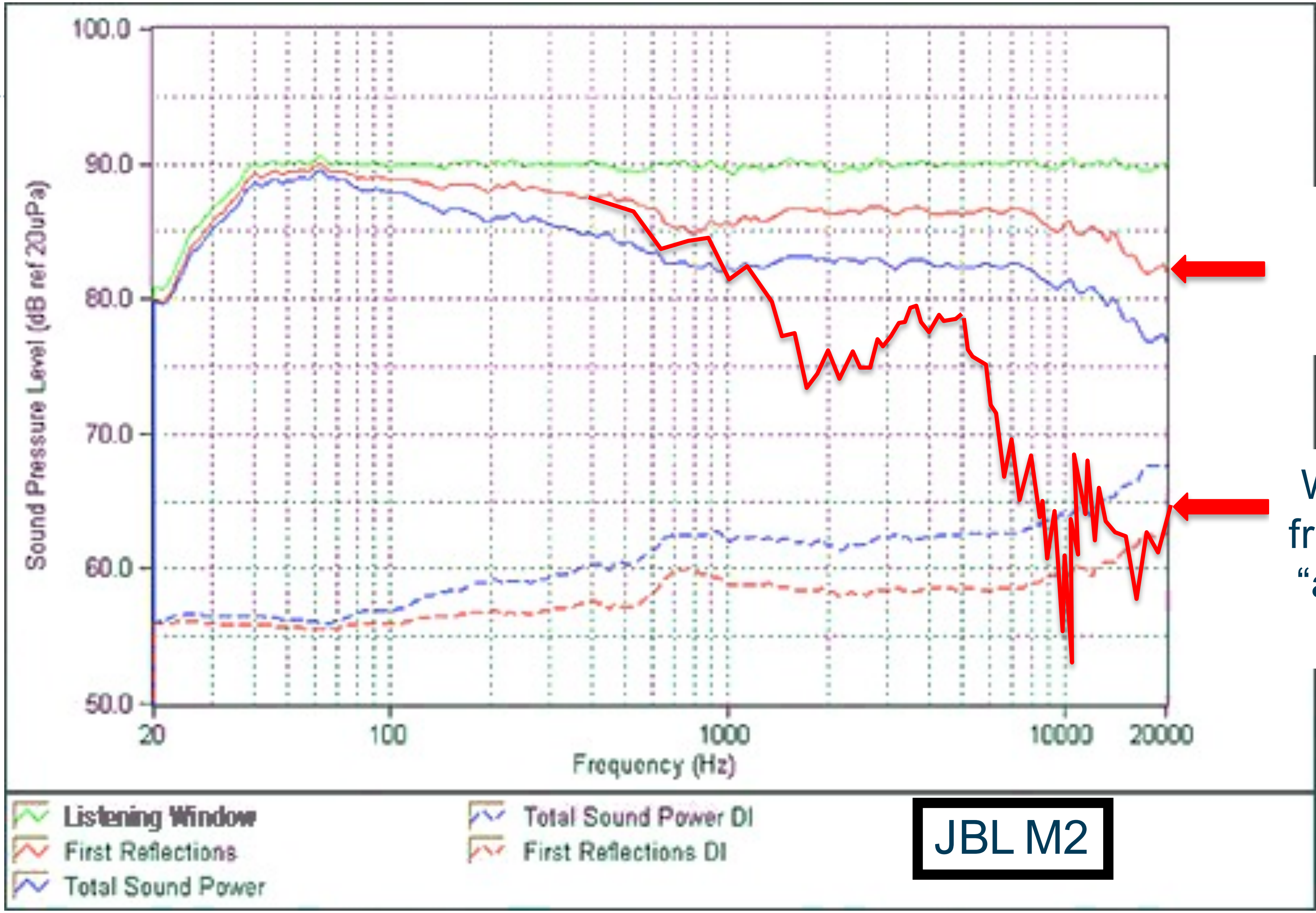


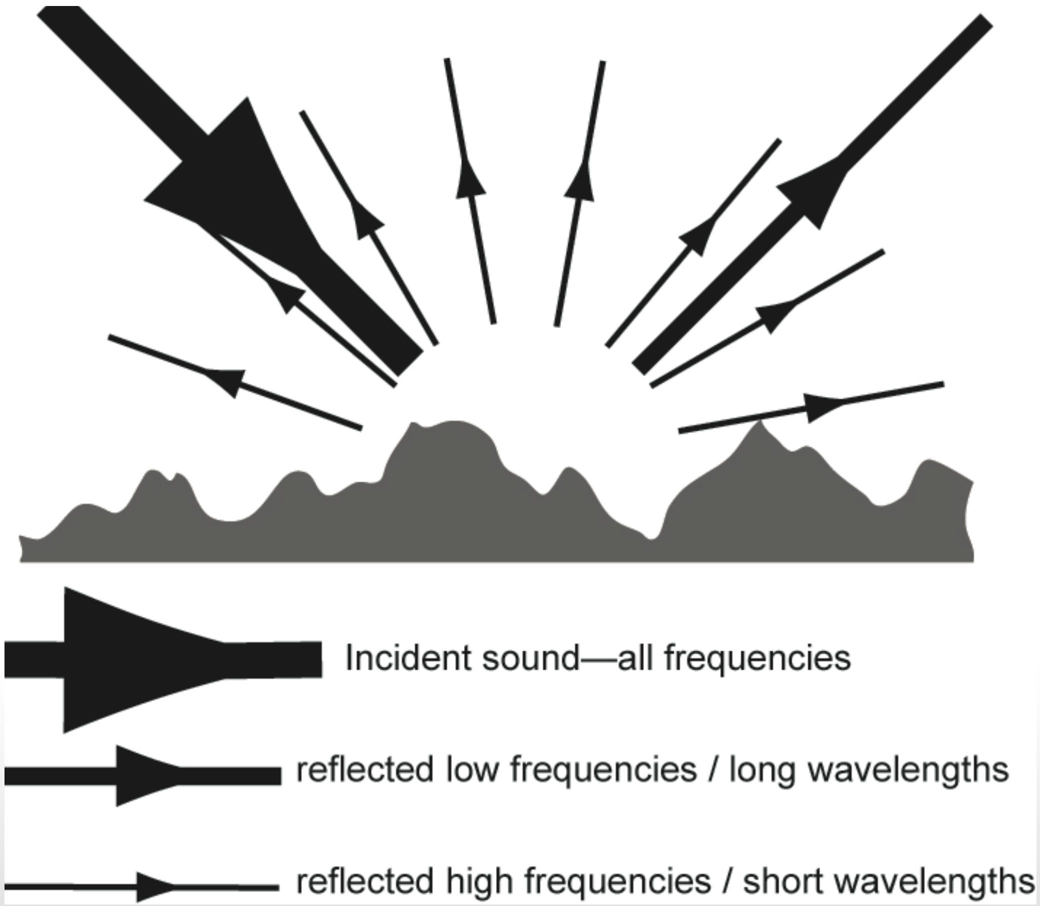
What left the excellent loudspeaker

What is reflected from the imperfect “absorber” on the wall

How can we avoid degrading a good loudspeaker?

- Use much thicker fiberglass or acoustic foam – not less than 3-4 inches (76-101 mm) – more is better.
- Remember that sculptured acoustic foam has to be twice as thick as slab/flat acoustic foam or fiberglass for the same absorption coefficient – half of it is air!
- The density of the fiberglass or fiberglass board is not important – it is the thickness that matters. High density boards were created for insulating flat roofs that could be walked on.
- Fiberglass, mineral wool, cellulose fiber, and acoustic foam all perform similarly.

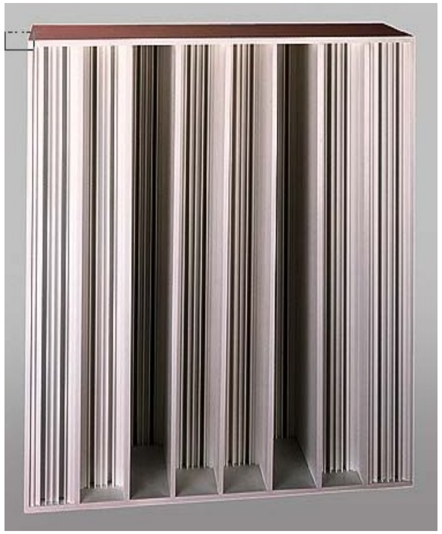
Sound scattering by diffusers



Thickness matters!

Diffusers are also used to attenuate reflections. To be effective down to 200-300 Hz, they must be thick:

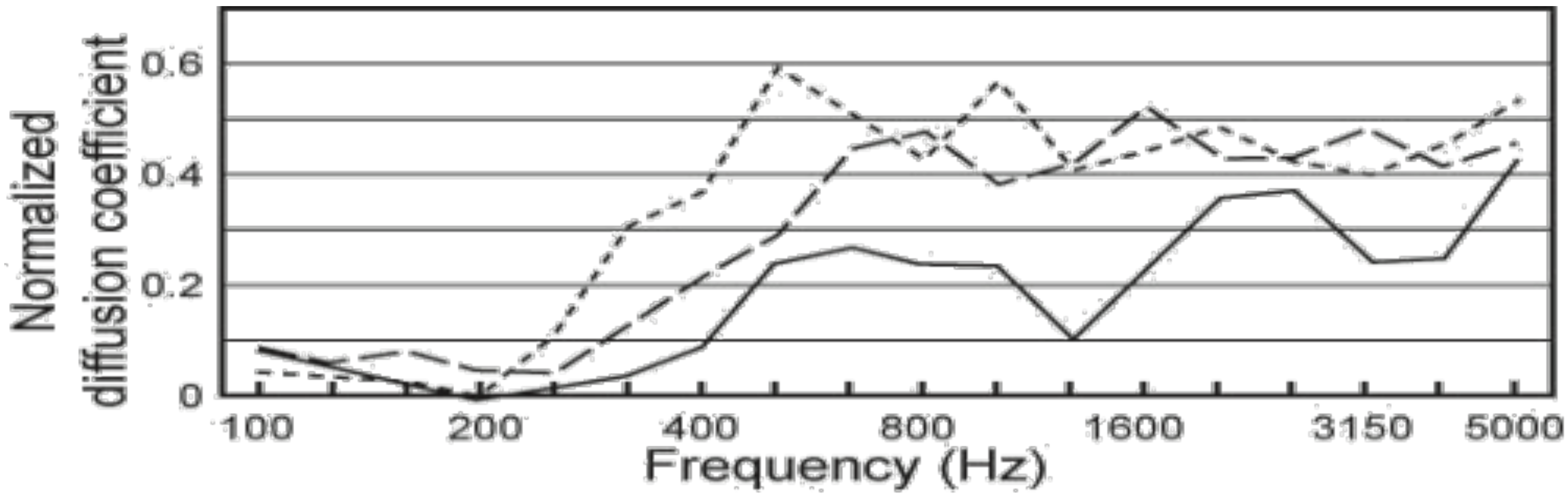
• 8 inches (200 mm) for engineered surfaces



•12 inches (300 mm)

for geometric shapes

“Engineered” surfaces – 8 in./0.2m

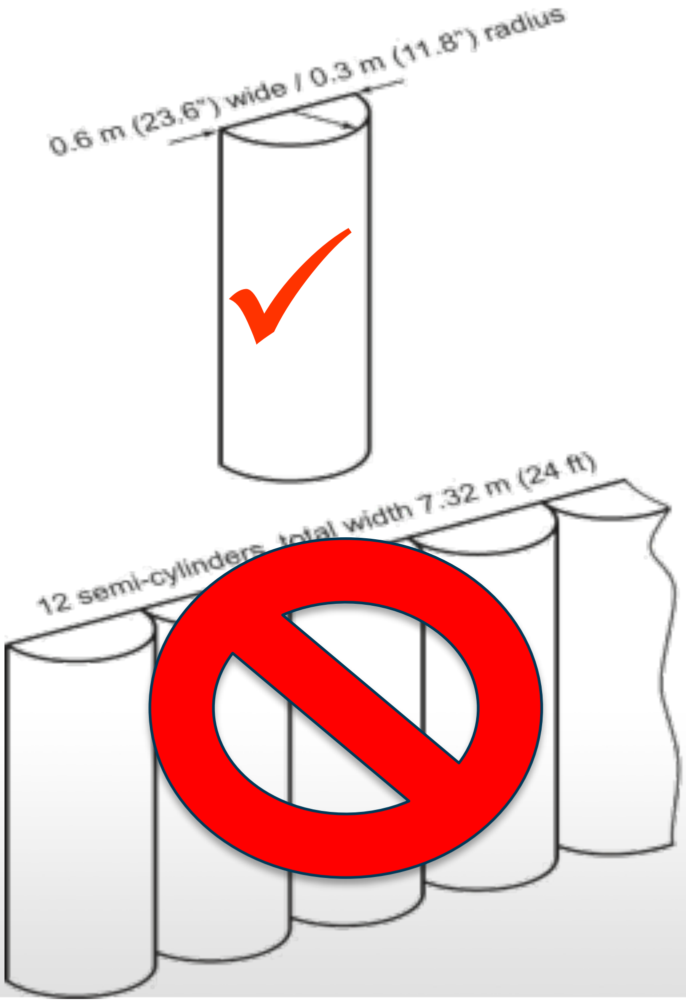


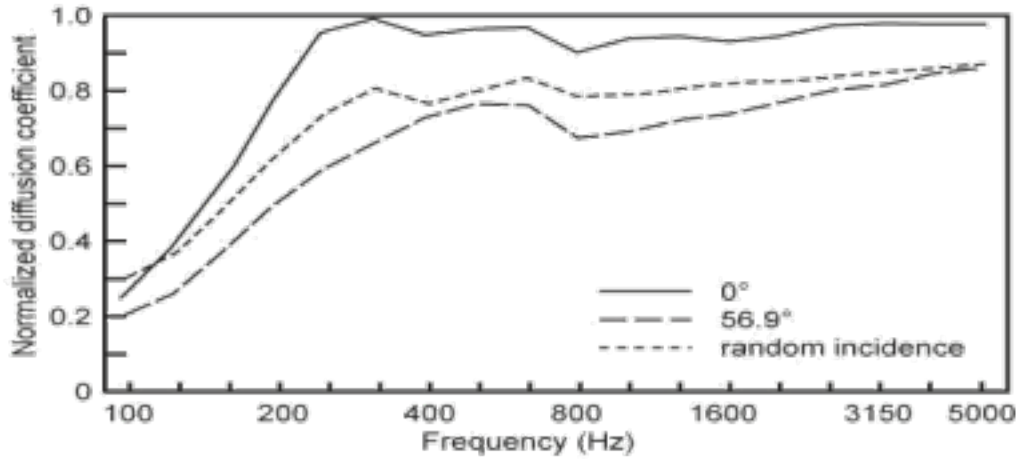
------ RPG Modffusor, 12 wells (modulated and optimized diffuser) 7.9 inches (0.2 m) deep

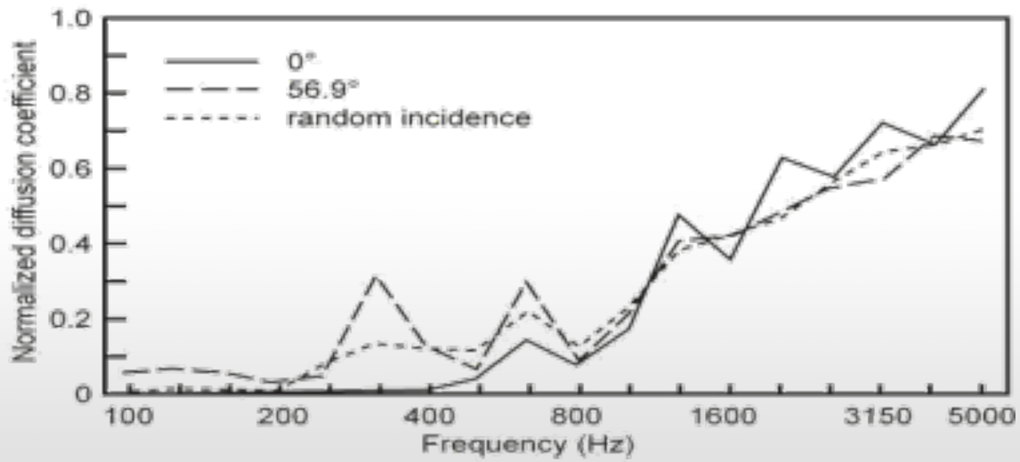
— — — RPG Modffusor, 8 wells (modulated and optimized diffuser) 7.9 inches (0.2 m) deep

——— Schroeder diffuser, N=7 QRD, 6 periods 7.9 in (0.2 m) deep, 12 ft (3.6 m) wide

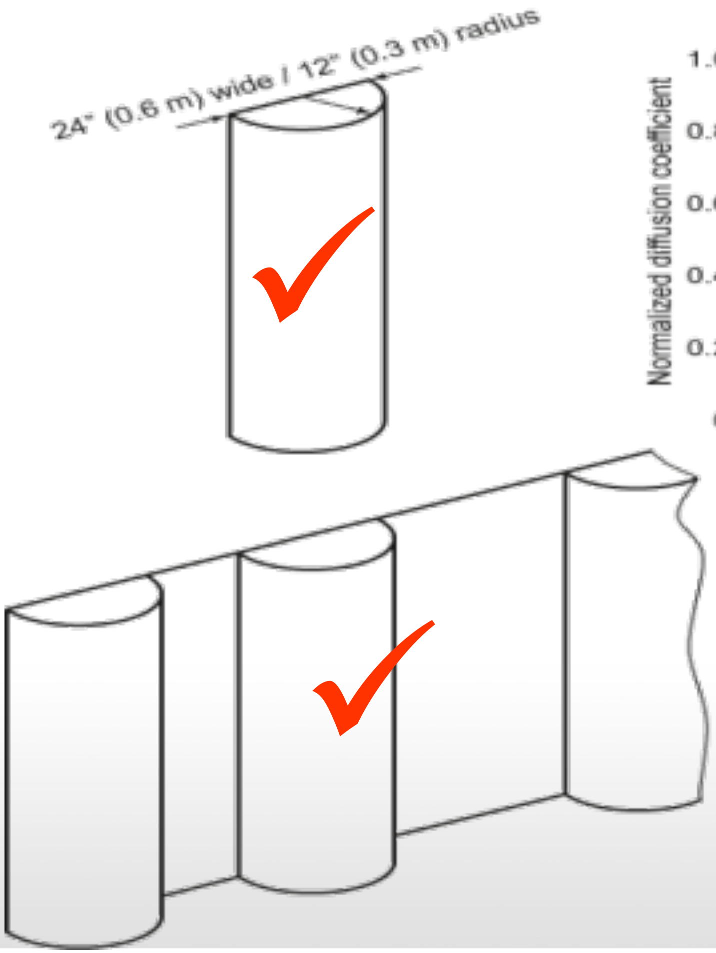
Use individually, or randomly spaced, not in rows

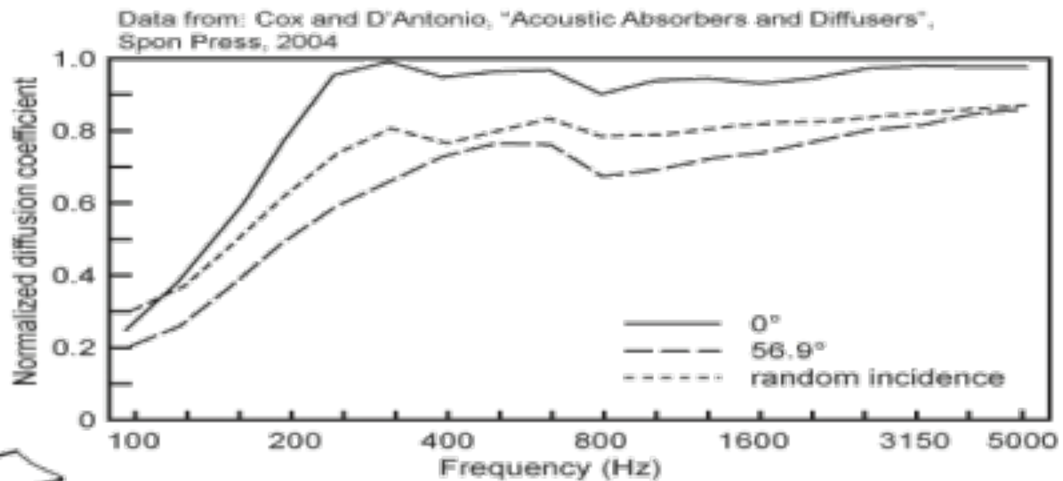




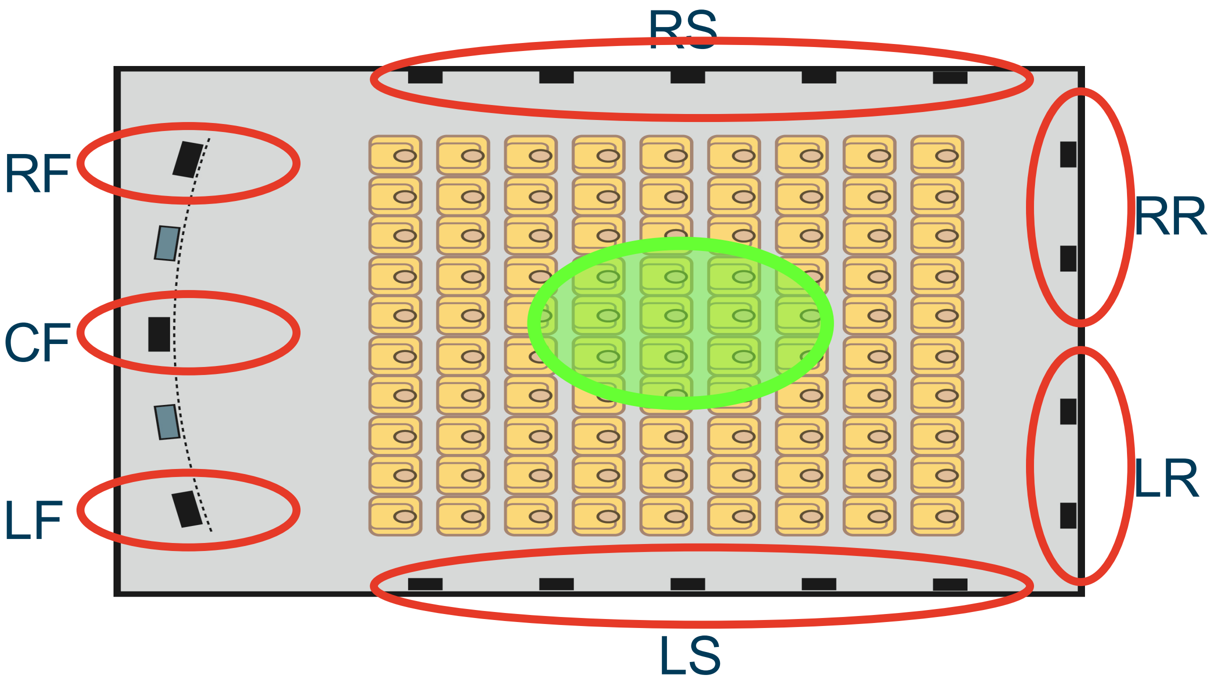


Use individually, or randomly spaced





The origin of 'surround sound'



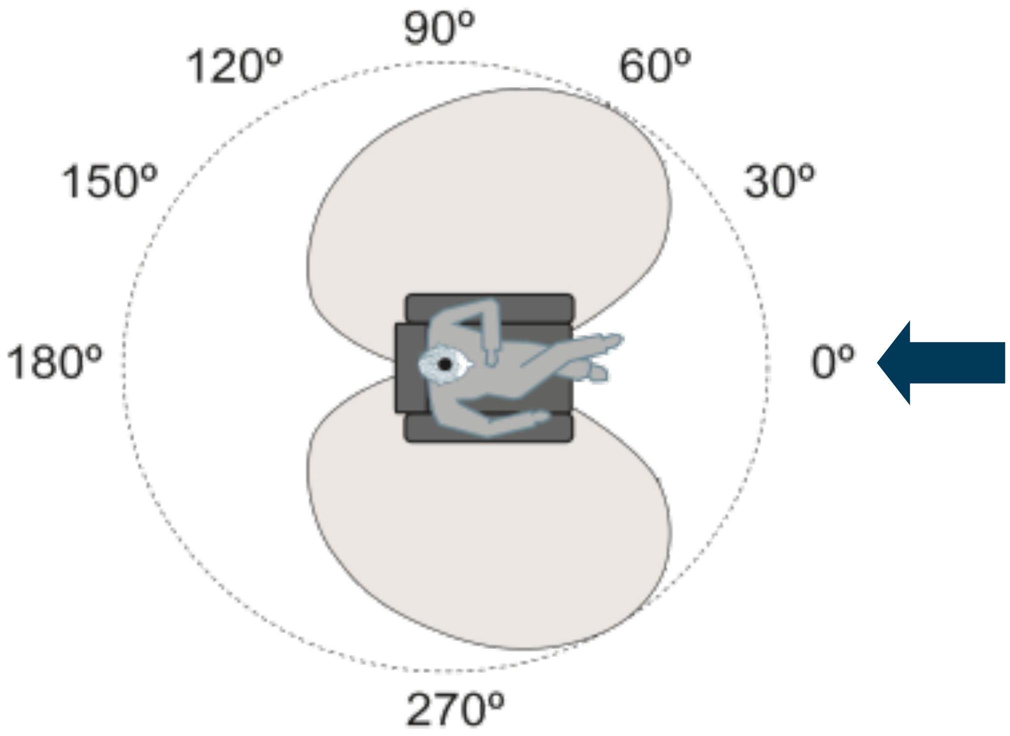
- Many loudspeakers but few channels.
- There still is a "prime" listening area and many less than ideal seats.

What is the purpose of surround sound?

- In movies the original reason was to create “envelopment”: the perception that you are in the same acoustical space that is seen on the screen.
- Now we can steer specific sounds to specific loudspeakers, sound effects like gunshots, door slams, and aircraft flyovers became localizable off-screen sounds.
- All of this was done with loudspeakers in the horizontal plane – even aircraft flyovers, which the brain interpret as being “up there”.

Interesting facts about envelopment

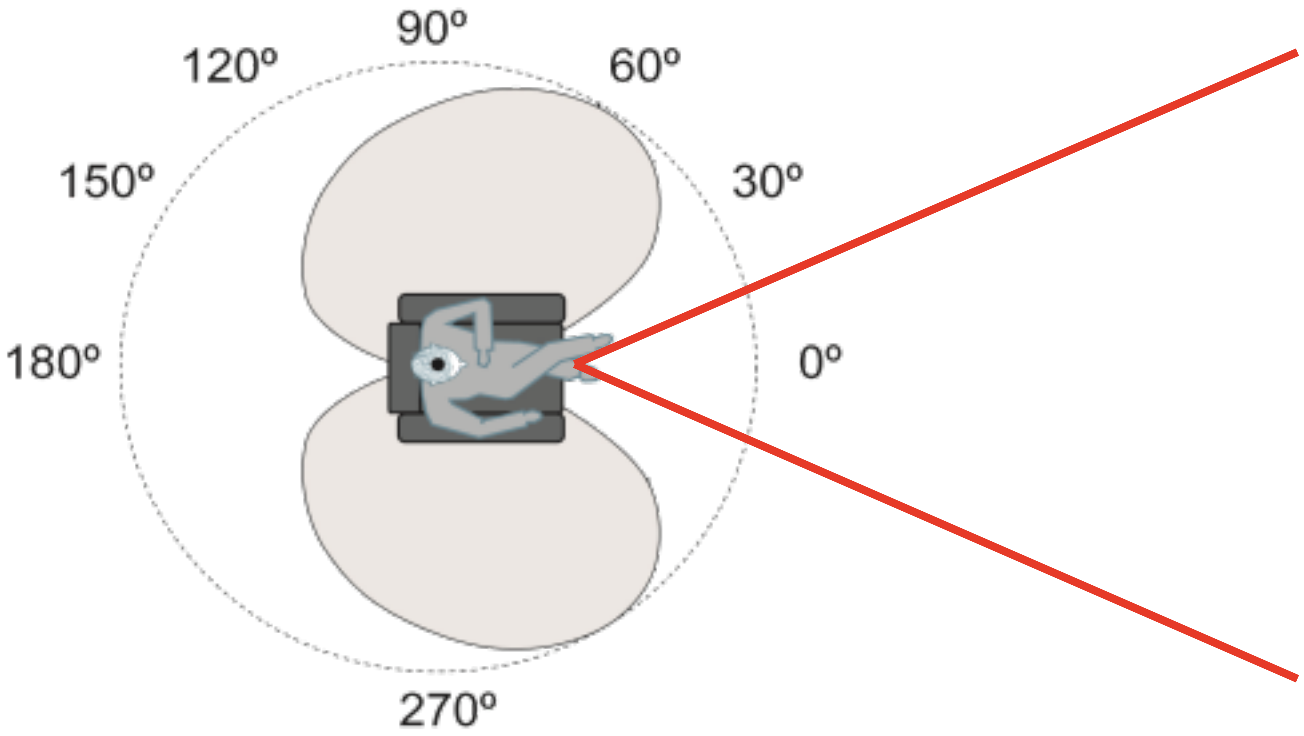
- Envelopment is perceived when the sounds at the two ears are uncorrelated – i.e different from each other.
- This is maximum when sounds arrive from the *sides*.



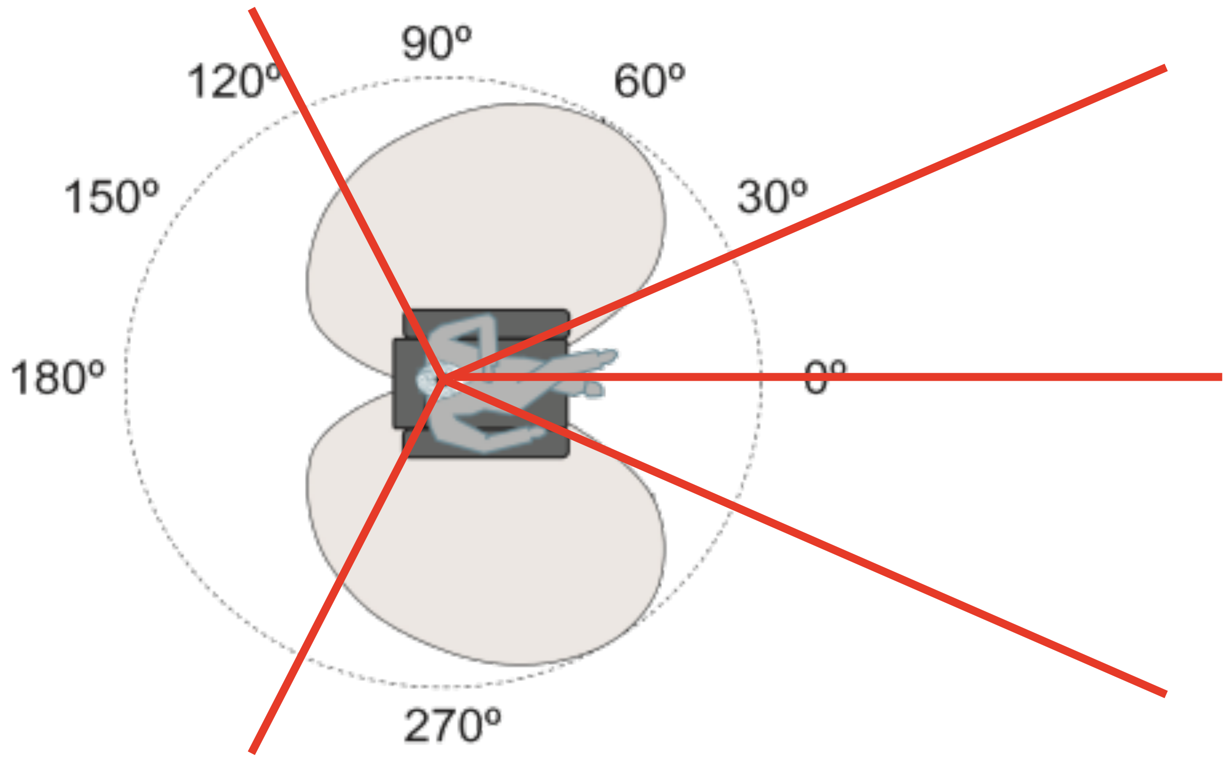
DIRECT SOUND

This is important!

Reflected or delayed sounds *<u>following the direct sound</u>*, arriving from different directions generate different amounts and kinds of spaciousness.



Stereo is not ideally suited for creating spaciousness.



DIRECT SOUND

But 5 channels do very well

The *only* reason for side surround speakers being slightly behind the listener is for “flyover” effects.

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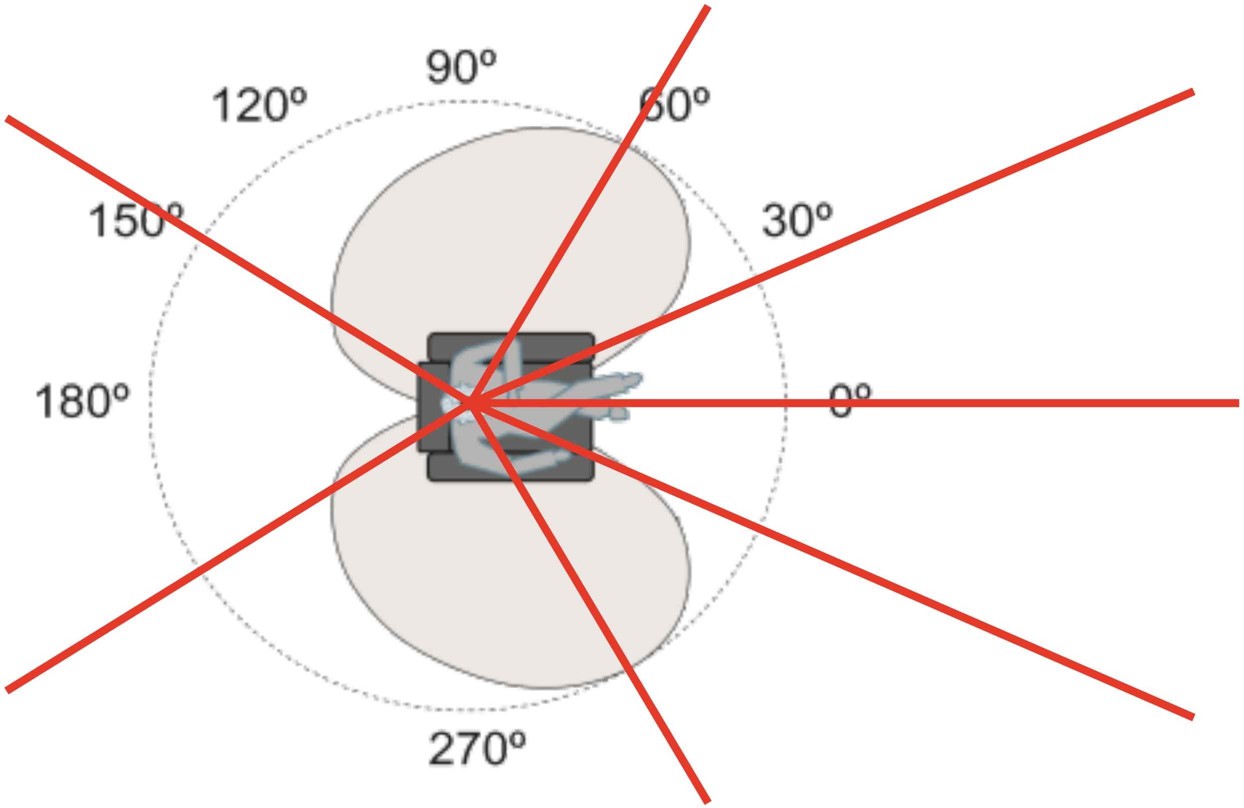
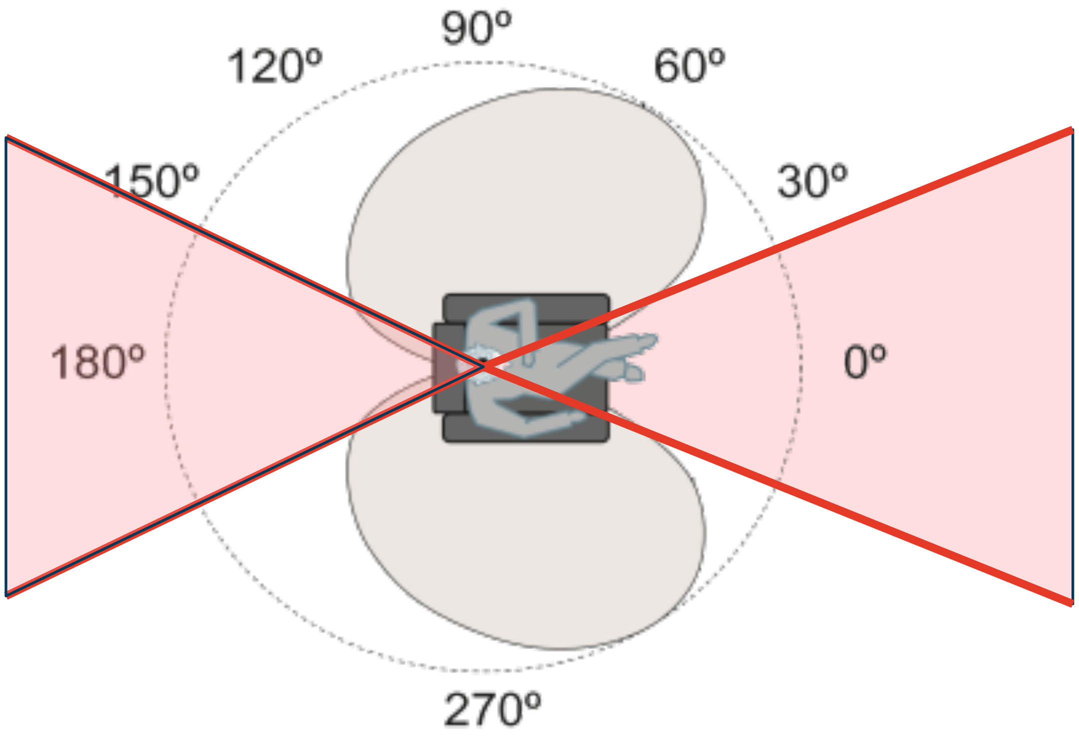


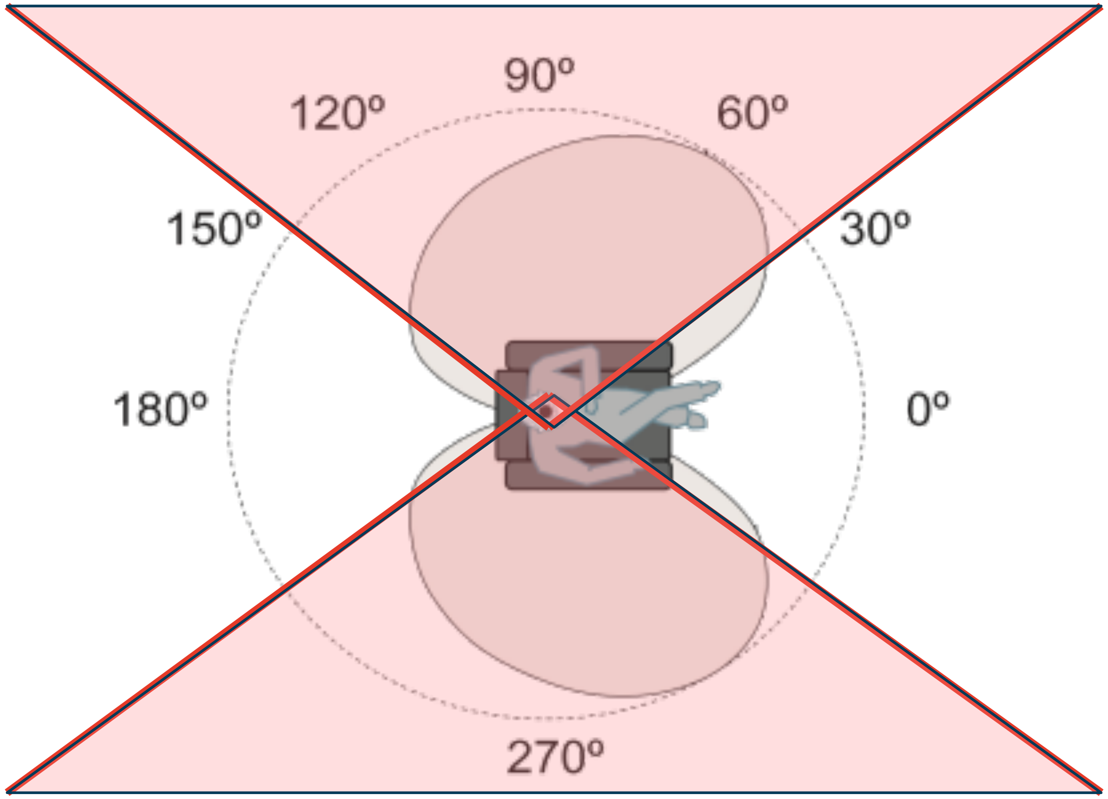
DIRECT SOUND

And 7 channels do even better,

With rear channels to provide “flyover” effects, the side channels can be moved forward for improved spaciousness/envelopment.

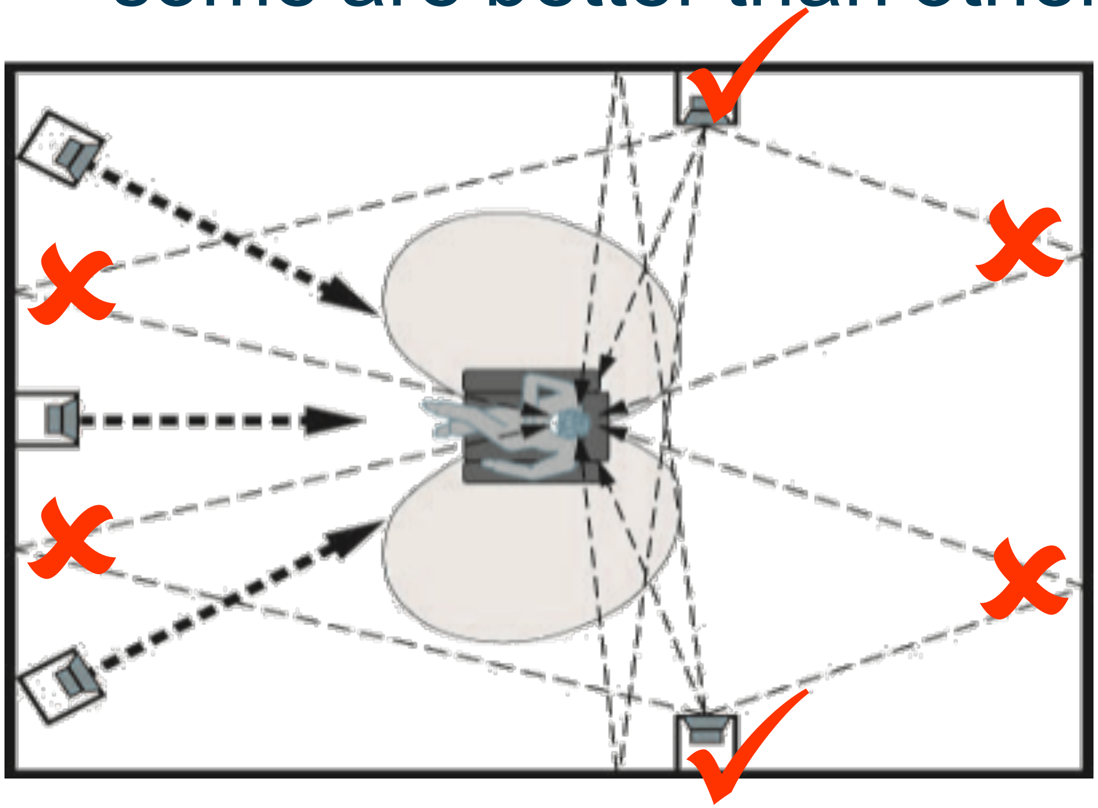


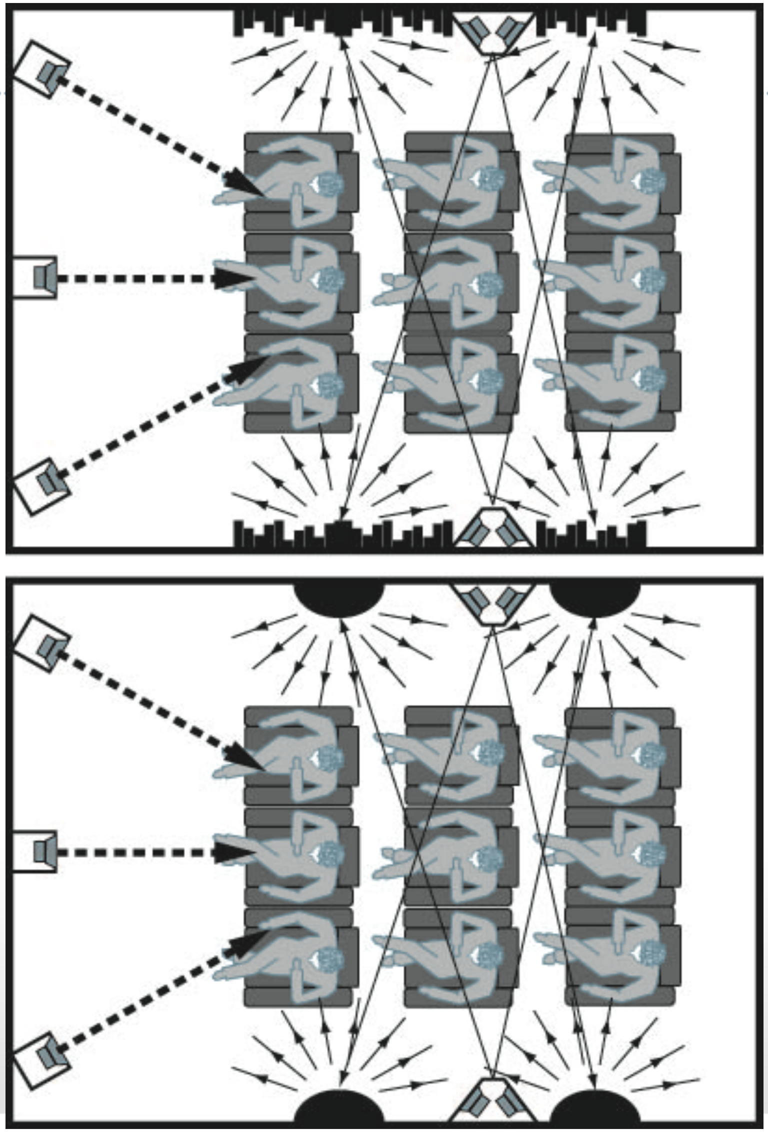
Delayed sounds arriving from these directions are not very effective at creating spaciousness.
Poor locations for “surround” speakers. Good locations for sound absorbers.



Delayed sounds arriving from these directions are very effective at creating spaciousness. Good locations for surround speakers – and scattering/diffusing surfaces.

Reflections can assist in creating envelopment, but some are better than others.

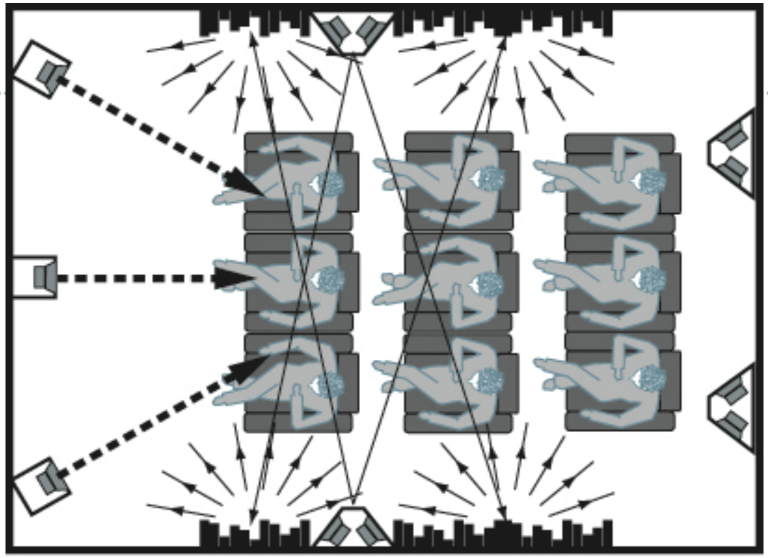


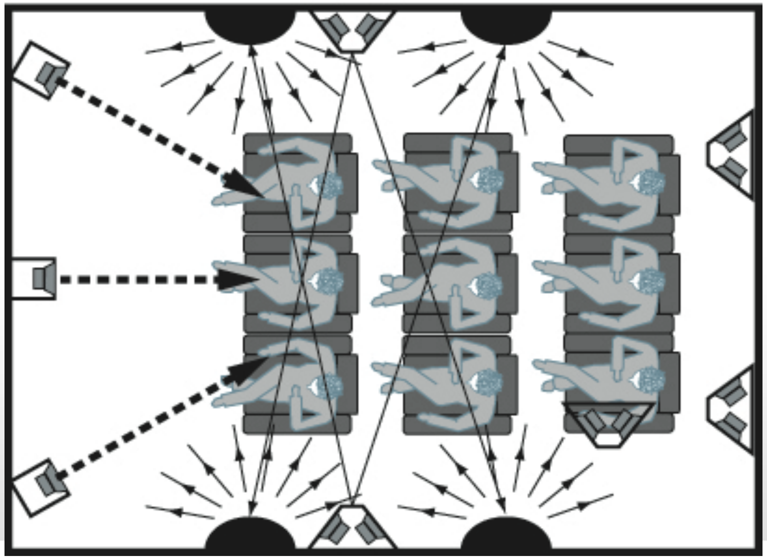


An optimized surround channel configuration using bidirectional in-phase (bipole) loudspeakers

(5.1 channel version)

- Strong direct sounds to all listeners
- Optimum arrival angles for envelopment for all listeners
- Envelopment for all listeners enhanced by diffusers





An optimized surround channel configuration using bidirectional in-phase (bipole) loudspeakers
(7.1 channel version)

- Strong direct sounds to all listeners
- Optimum arrival angles for envelopment for all listeners
- Envelopment for all listeners enhanced by diffusers

The “prime listening location”

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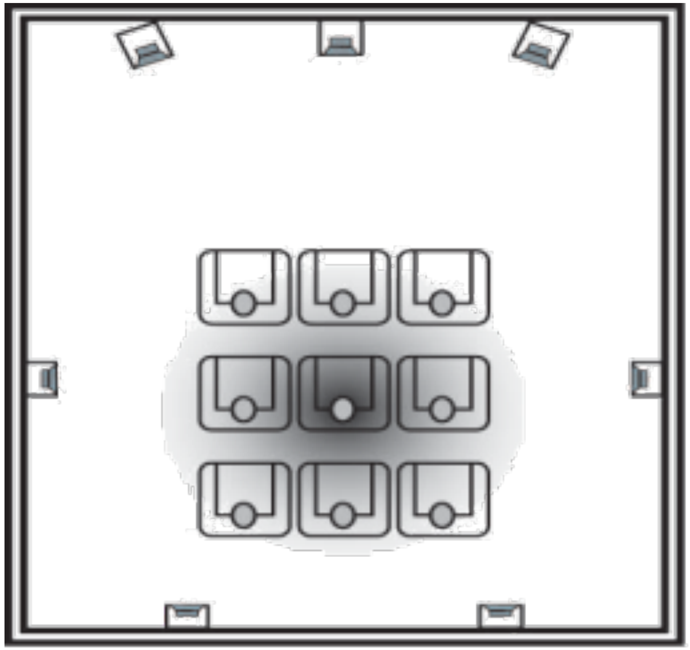
It is the best seat in the house, because:

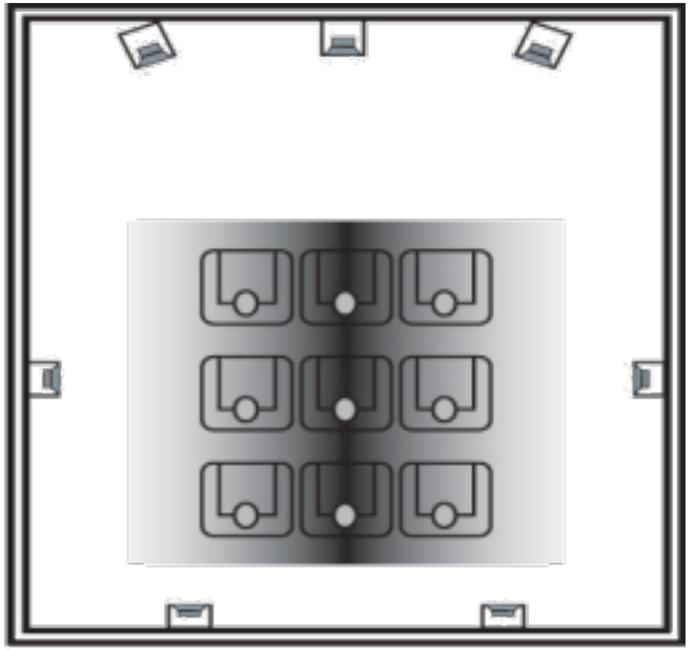
- The video display and the locations of all loudspeakers are determined with reference to this seat.
- All calibrations of sound level and arrival time are done for this seat.
- The best sense of envelopment occurs on the front-back center line of the room.
- Therefore, if possible, **every theater** should have a prime listening location, a.k.a. the “money seat”, the “sweet spot” on the center line of the room!

So, where does one sit?

To hear the “calibrated” multichannel experience



To hear the best envelopment



Every home theater *must* have a seat at the “sweet spot”, and preferably others on the center line.

What loudspeaker should I use for surrounds?

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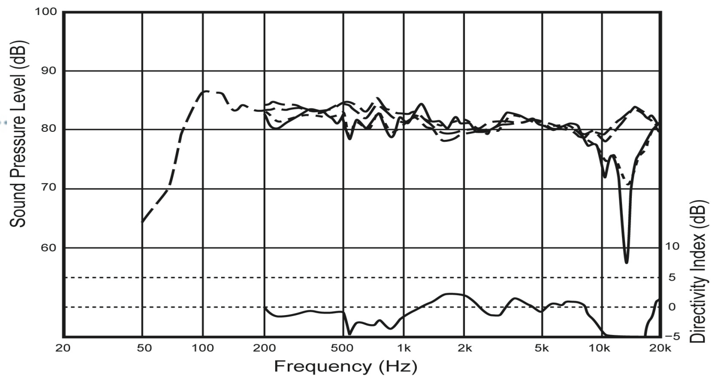
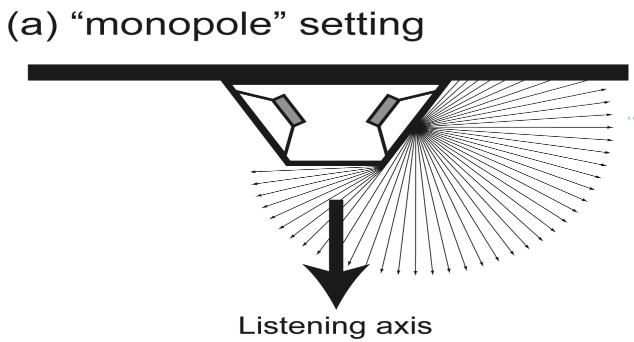
Conventional forward firing loudspeakers? Yes, if they can deliver good direct sound to all listeners. OK for small audiences.

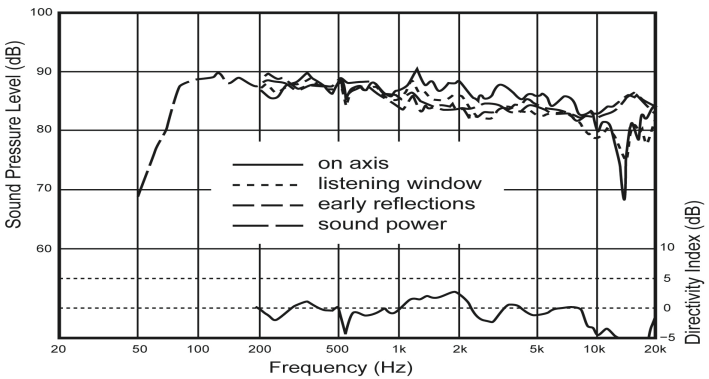
Bipole: bidirectional in-phase? Yes, especially for multiple rows.

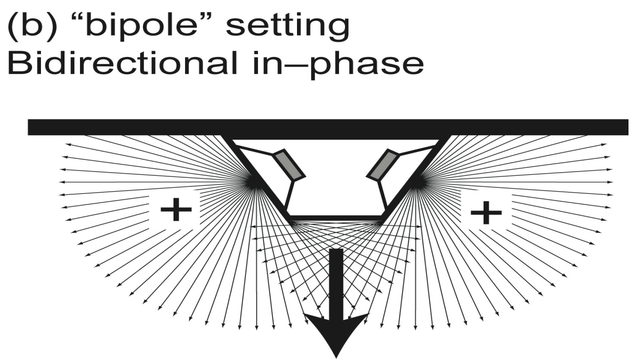
Dipole: bidirectional out-of-phase? No, they don't sound good, offer no advantages, and don't work for multiple rows.

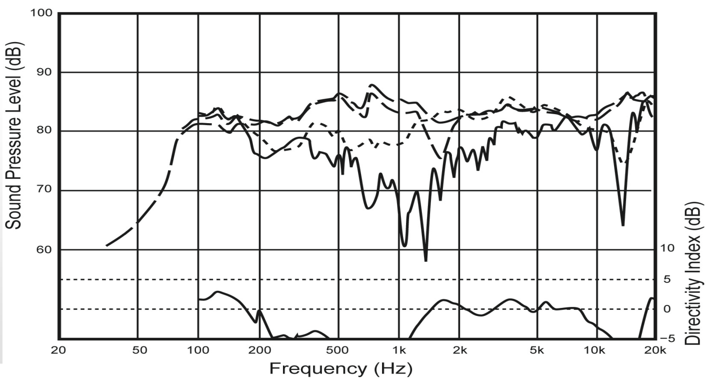
An on-wall surround loudspeaker with variable directivity

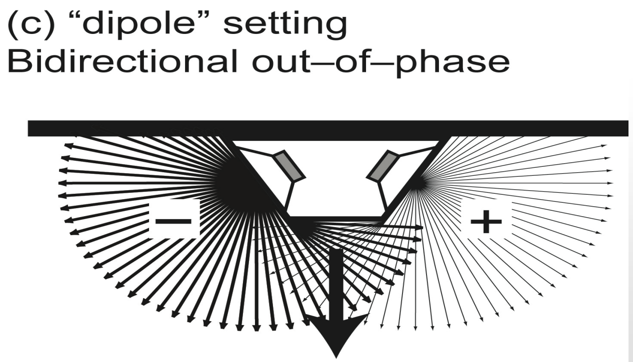








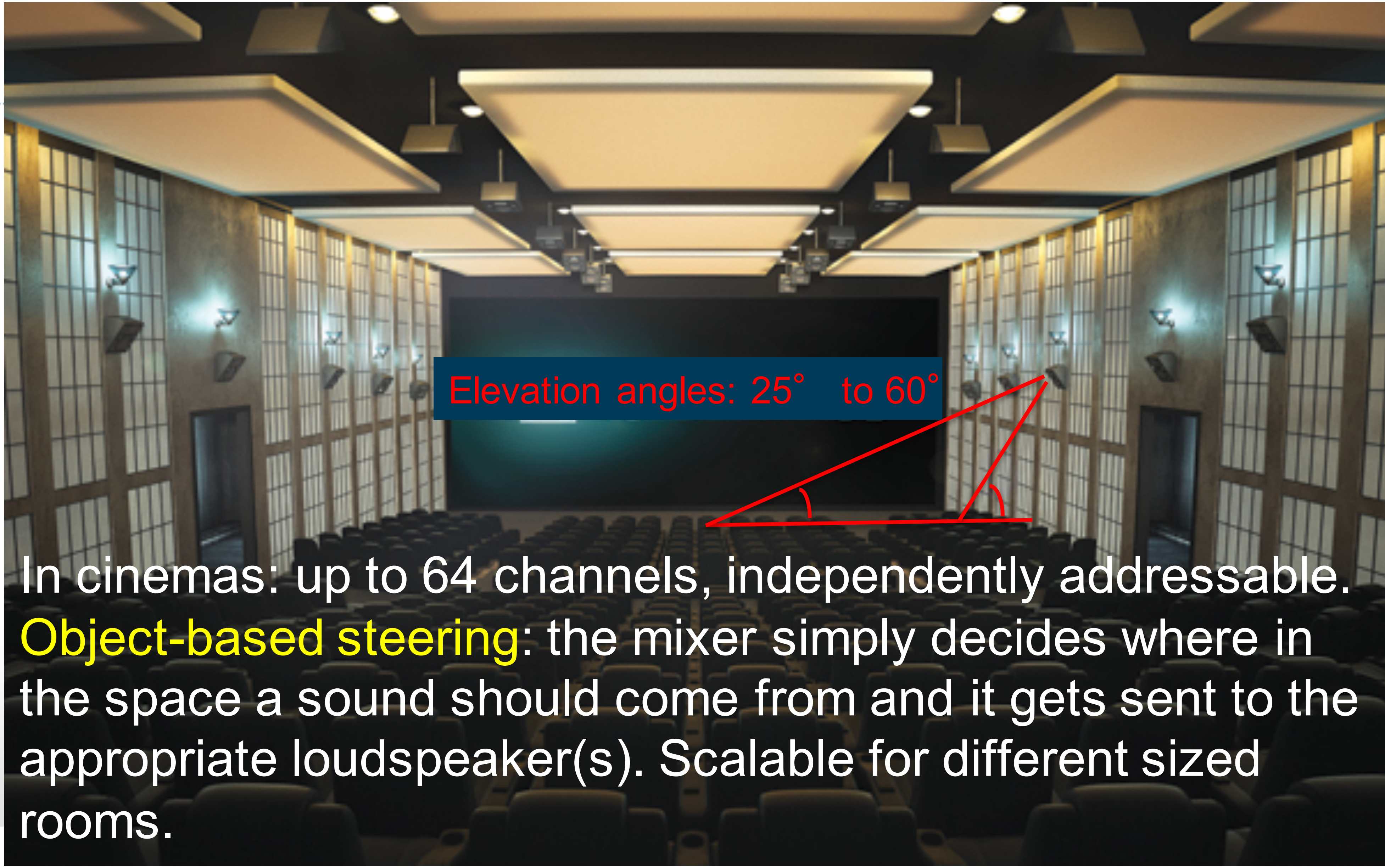




This does not look or sound good!

3-D “immersive” audio – adding height

- **Past efforts with height channels were not impressive.** The sounds emerging from the height loudspeakers were not sent there for any artistic reasons – they were extracted arbitrarily from the 5.1 channel mix and nothing we heard was intended by the mixer.
- **Current efforts: Atmos, Auro-3D and DTS-X work well.** They add many discrete channels that allow mixers to send any sound they like to any location – when we hear high sounds they were intended to be high.



In cinemas: up to 64 channels, independently addressable. Object-based steering: the mixer simply decides where in the space a sound should come from and it gets sent to the appropriate loudspeaker(s). Scalable for different sized rooms.

Dolby Atmos for home theater: ceiling speakers

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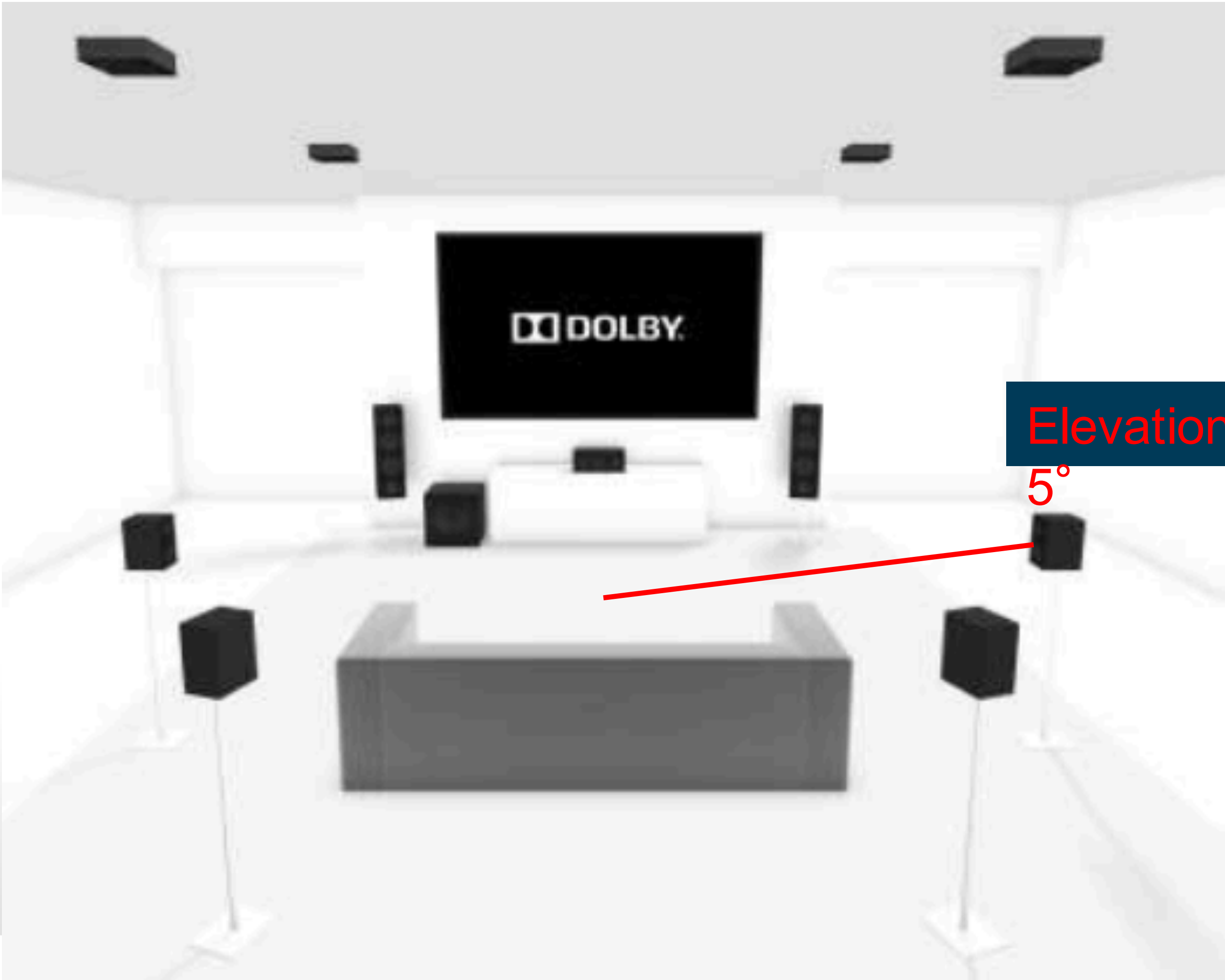

Dolby Atmos for home theater: reflected sound

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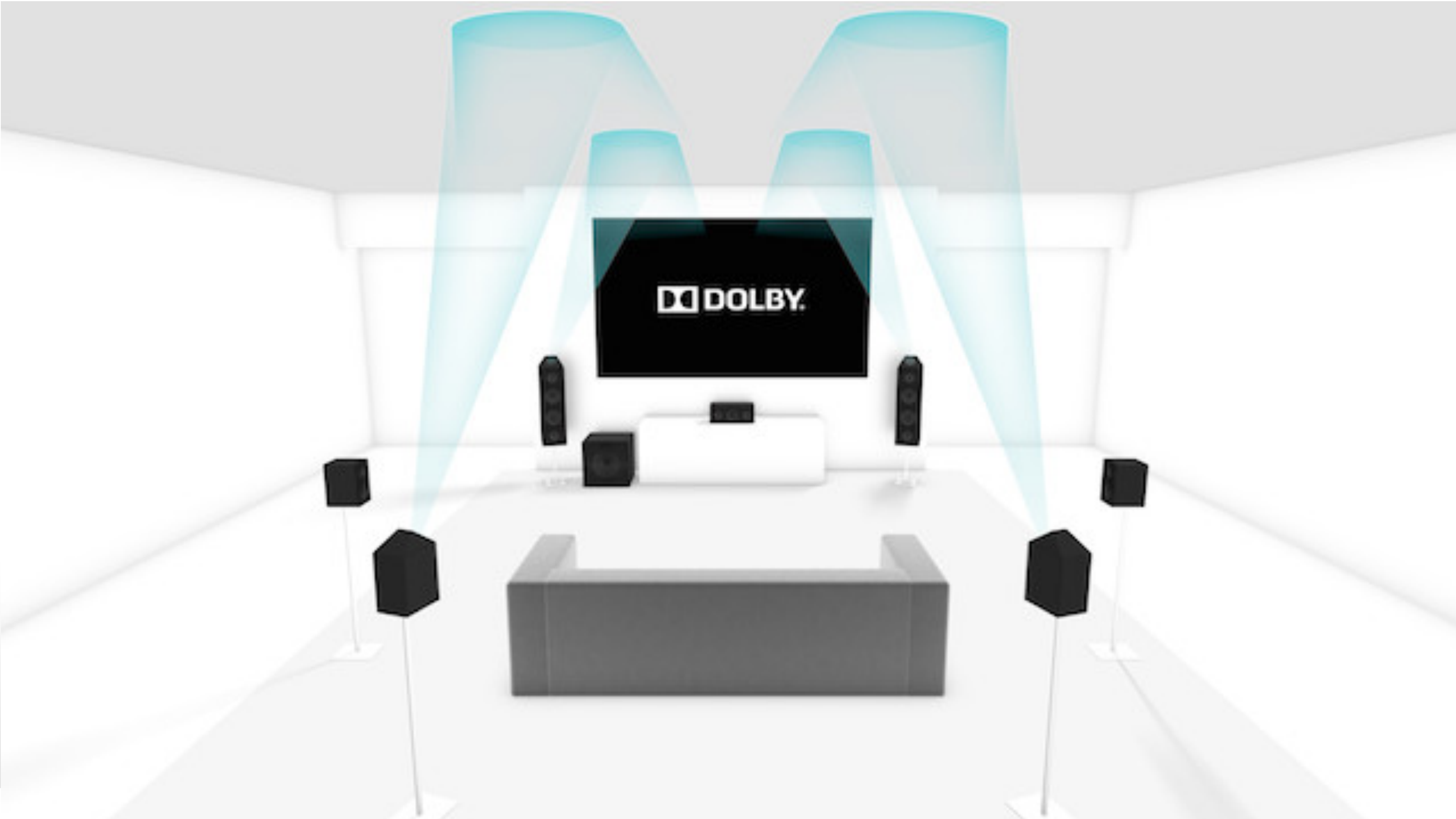

Audio Facts

In evaluations of overall sound quality, bass accounts for about 30% of the factor weighting.

People like, and can recognize, good bass!

Audio Folklore

TRUE ✔ or FALSE ✖

Are there "ideal" room proportions, or shapes, that minimize problems with bass in small rooms.

FALSE: And here is why . . .

Is There an "Ideal" Room Shape?

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Louden
1:1.4:1.9

Golden Rule
1:1.62:2.62

Toole
1:?:?

Knudsen
1:1.25:1.6

Olson
1:1.25:1.6

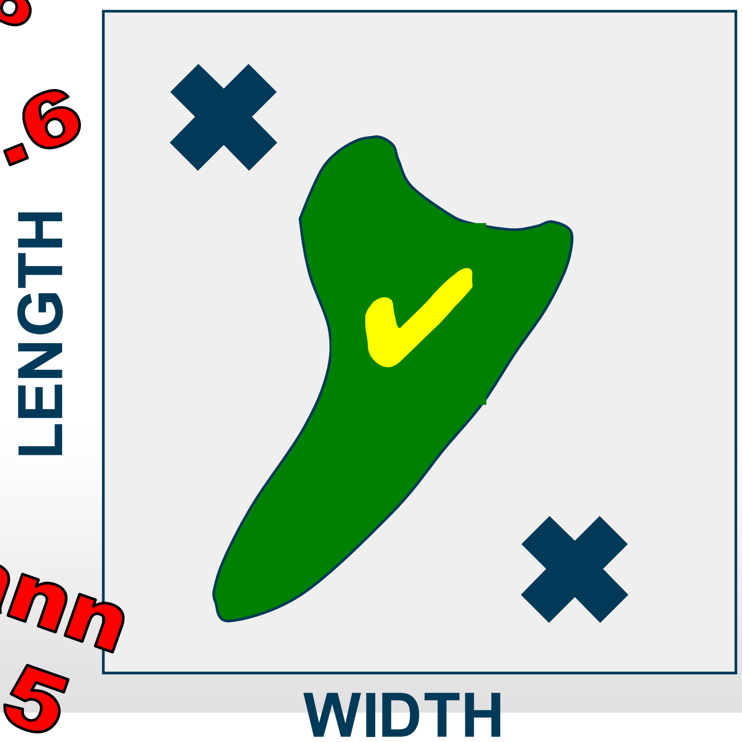
EBU Tech 3276

1.1 w/h < l/h < 4.5w/h - 4

Sabine
1:1.5:2.5

Volkmann
1:1.6:2.5

Bolt



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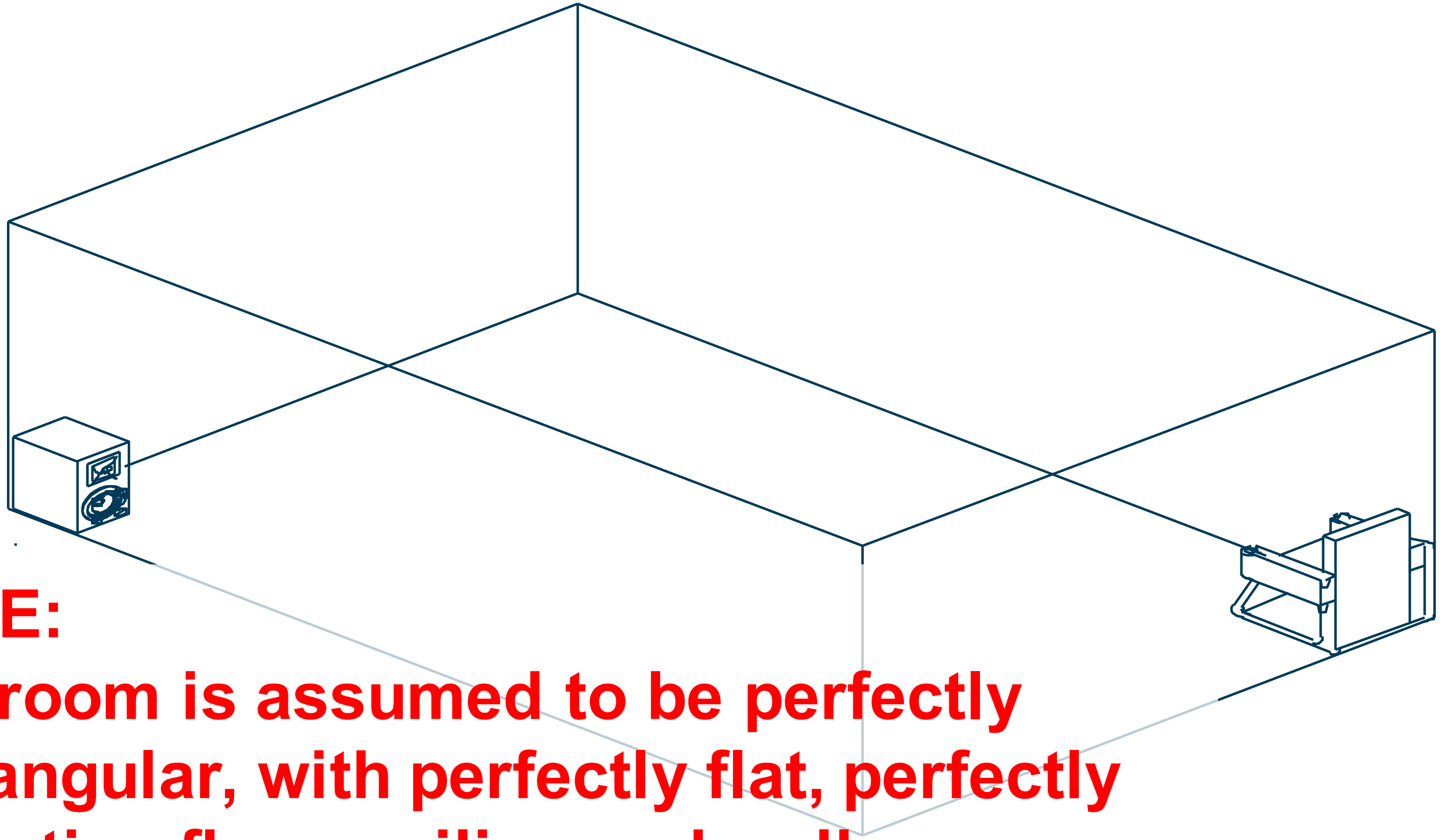
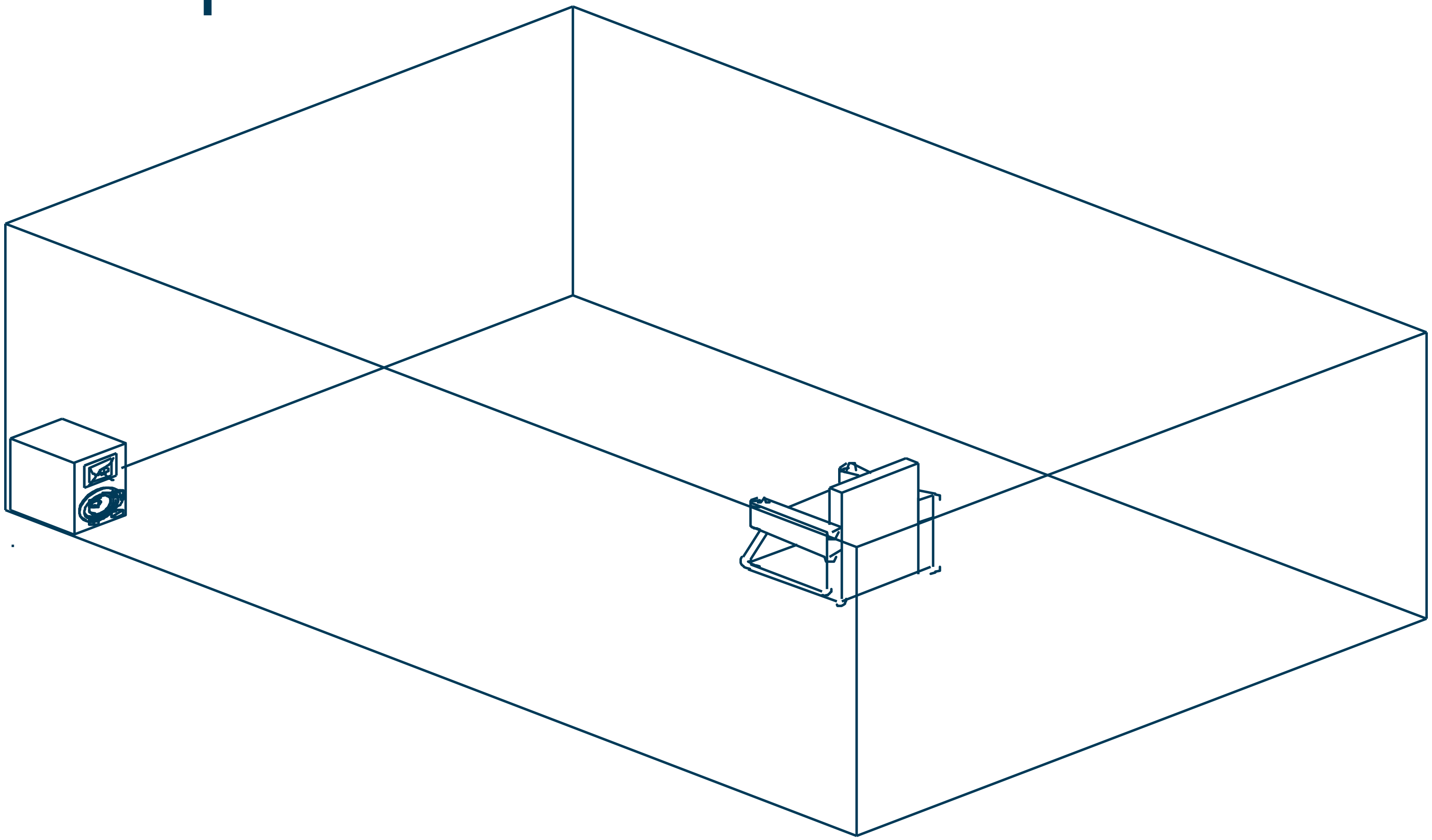
None of this is wrong, but, in sound reproduction, it is *irrelevant!*

The listening arrangement assumed for 'ideal room' calculations.

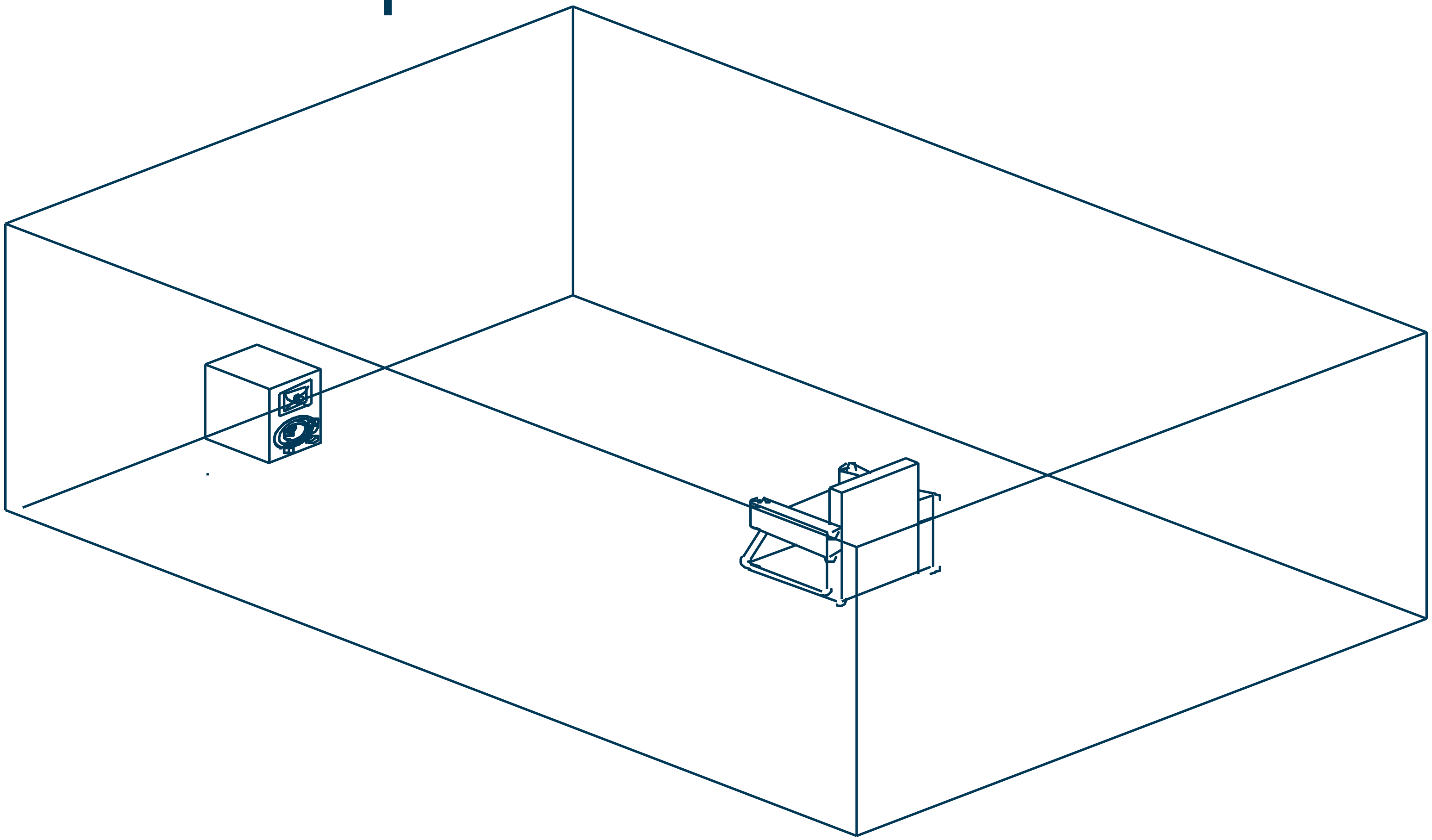


NOTE:
The room is assumed to be perfectly rectangular, with perfectly flat, perfectly reflecting floor, ceiling and walls.

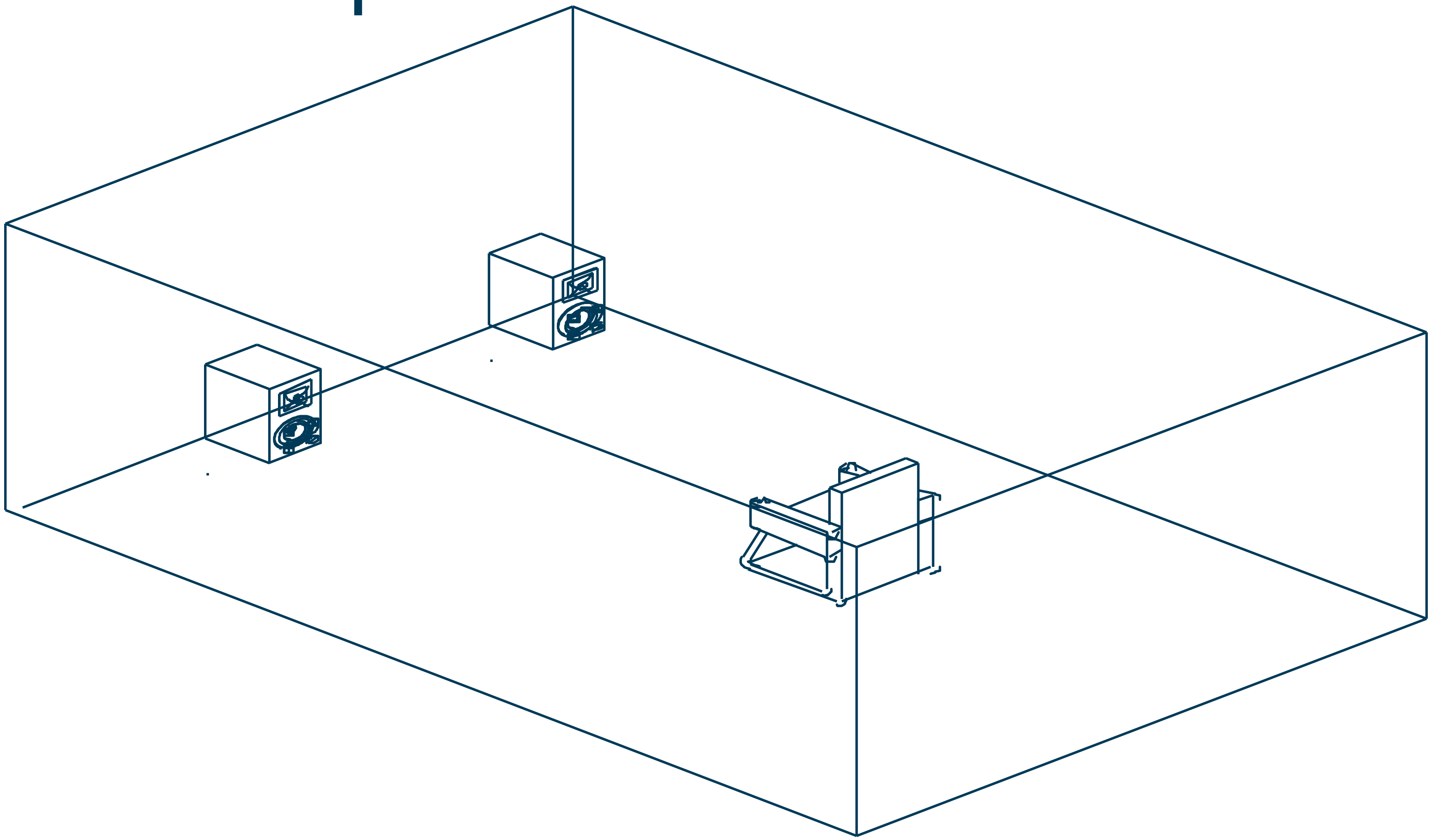
A practical listening location does not couple to all of the modes.



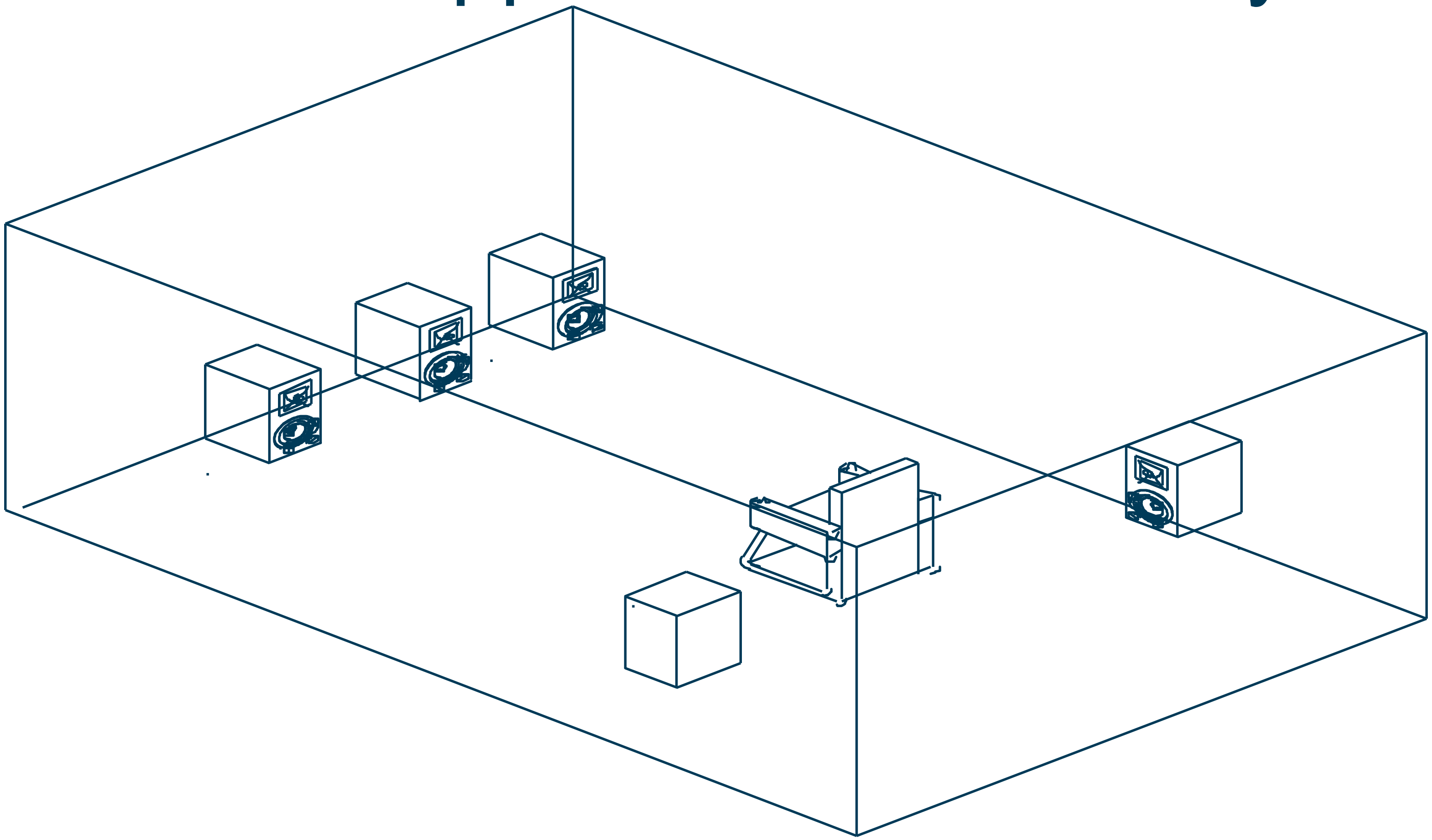
A practical loudspeaker location does not couple to all of the modes.



Two loudspeakers void the predictions.



And with five or more loudspeakers a whole new approach is necessary!



Which is why none of these work!

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Louden
1:1.4:1.9

Golden Rule
1:1.62:2.62

Knudsen
1:1.25:1.6

Olson
1:1.25:1.6

EBU Tech 3276
1.1 w/h < l/h < 4.5w/h - 4

Sabine
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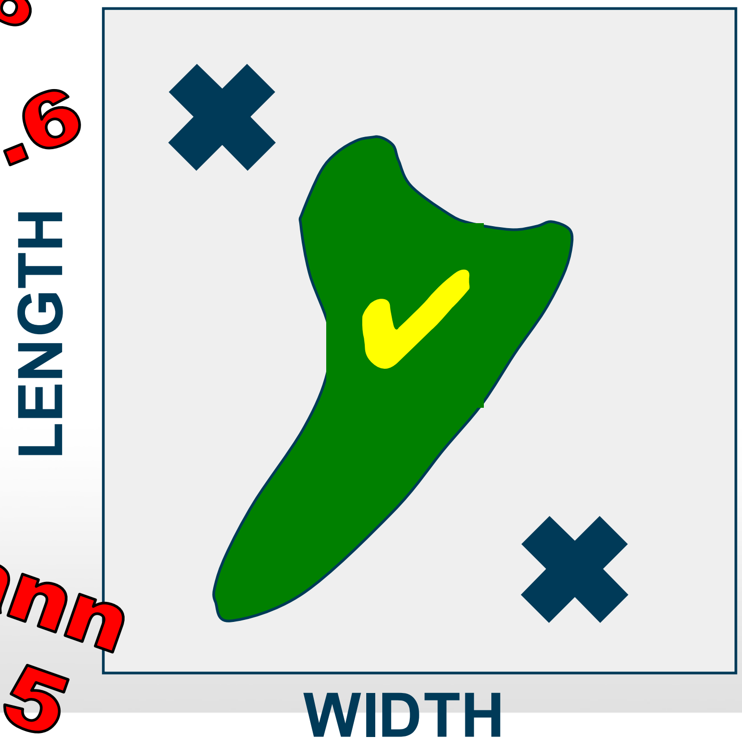
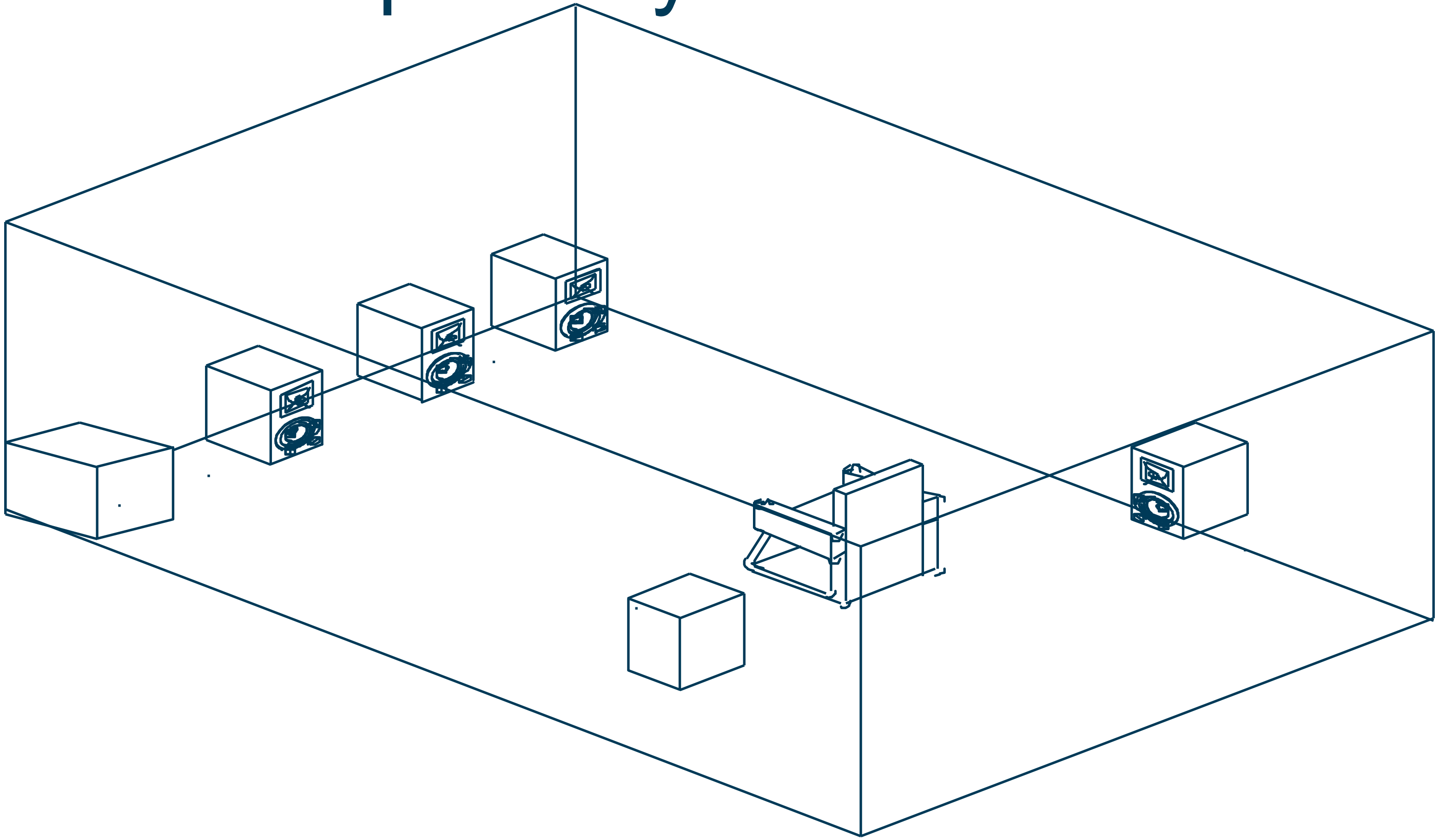
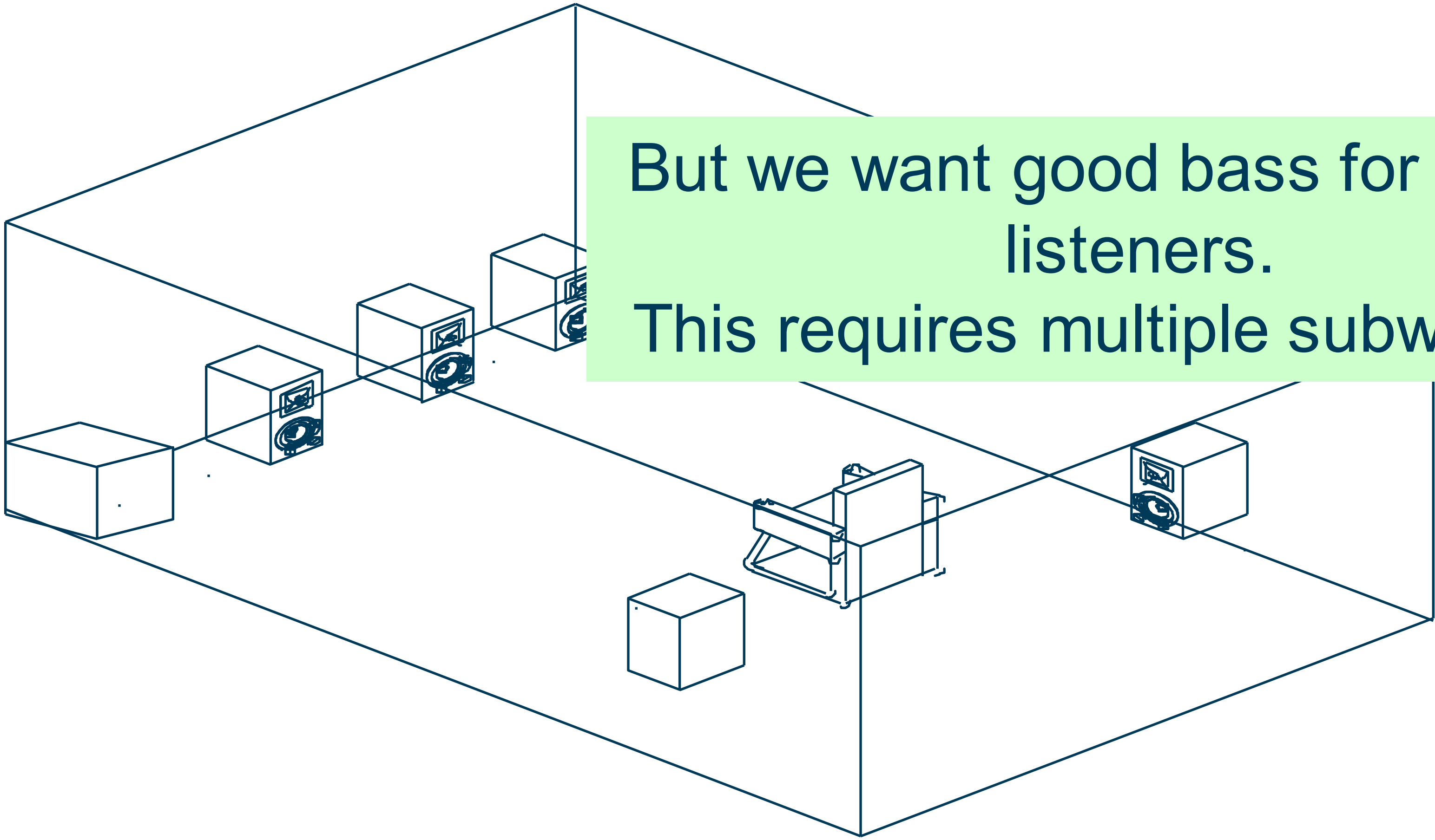


And which is why dealing with the bass separately is sensible.



1 subwoofer + 1 equalizer ≈ good bass for 1 listener. Same bass for all channels!



But we want good bass for several listeners.
This requires multiple subwoofers.

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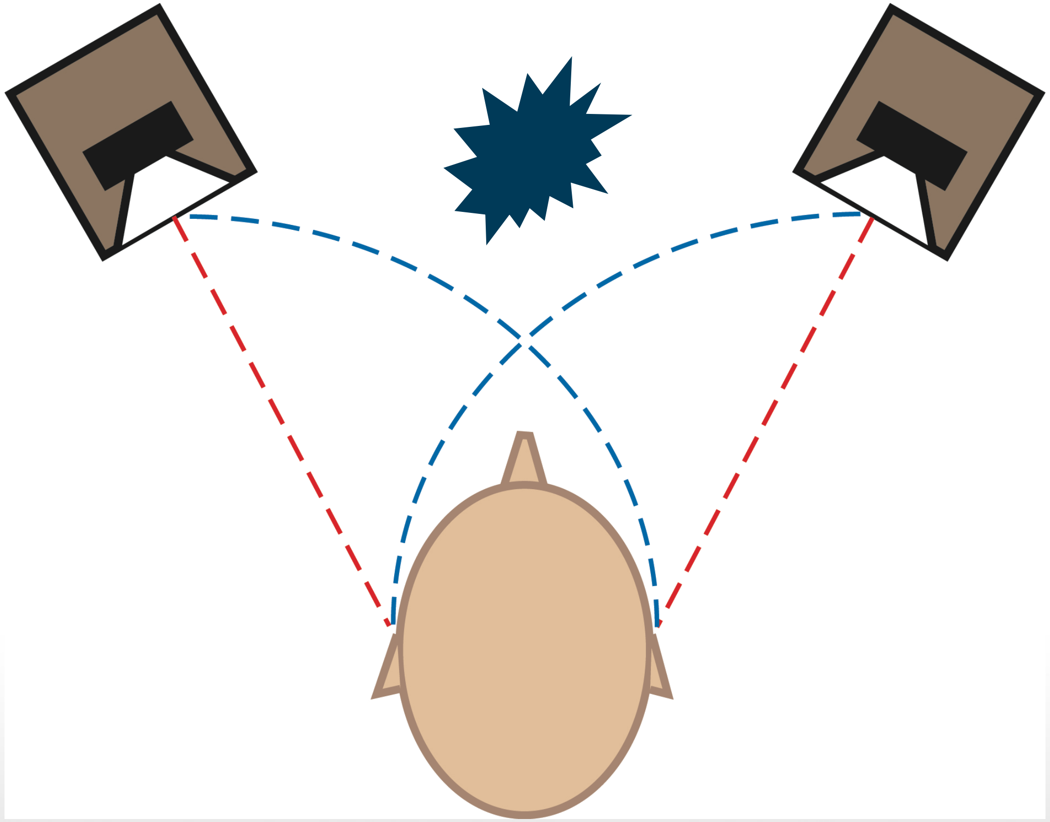
Multiple subwoofers can deliver great bass to several listeners:

Improved solutions for simple rectangular rooms.

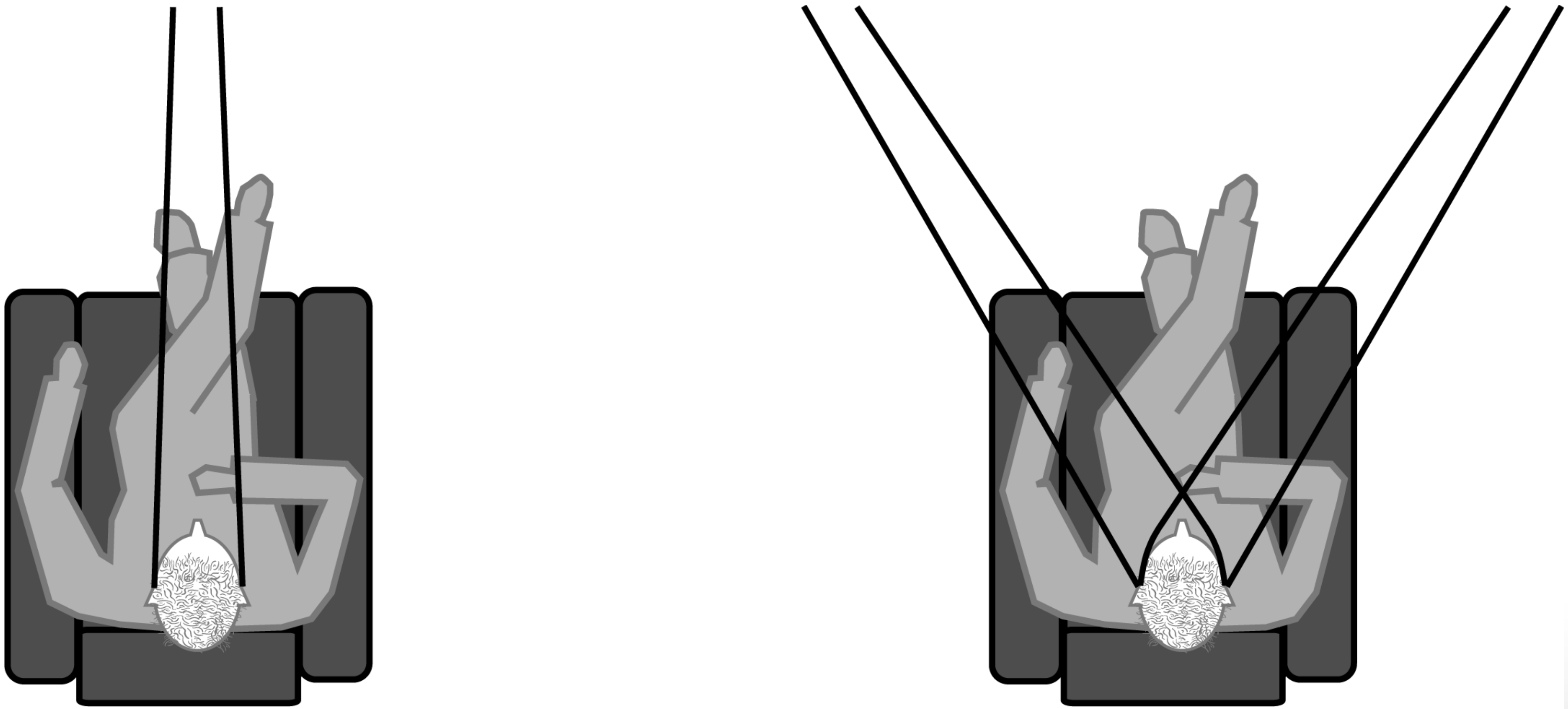
The best solution: Sound Field Management (SFM) for any rooms.

Why a center channel is a good idea



- A phantom image is created by identical sounds radiated by both speakers (mono)
- This results in *two* sounds at *each* ear instead of one

Why a center channel is a good idea



(a) a real center loudspeaker

(b) a stereo phantom center

Phantom images have problems!

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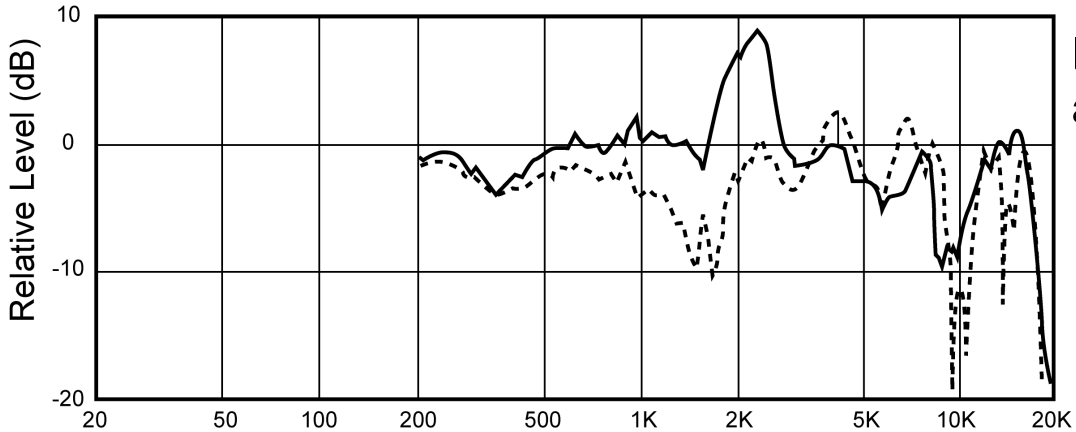
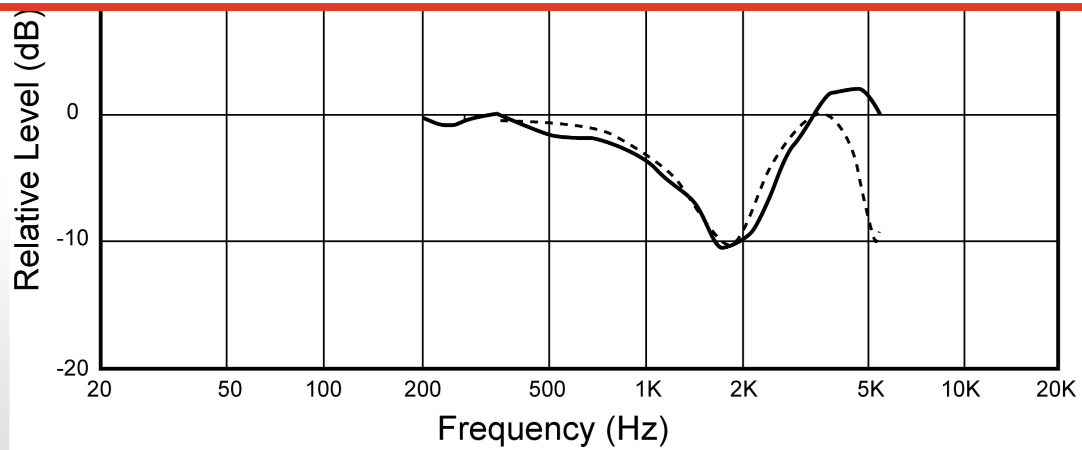


Frequency response measured at one ear for sounds arriving from:

- (solid line) one center loudspeaker
- (dashed line) a stereo pair of loudspeakers producing a phantom image

This is the frequency response error in stereo center images!



- (solid line) the difference between the curves
- (dashed line) the interference pattern (comb filtering) for two sounds, the later one delayed by 0.27 ms and attenuated by 6 dB.

Phantom images have problems:

- The dip in the frequency response is audible as a coloration in all sounds. (Note: side wall and other room reflections help to fill the dip – a good thing.)
- Speech intelligibility is significantly reduced.
- The location of the image is correct only for listeners seated on the center line of the room.

Lesson: use a center channel

Audio Folklore

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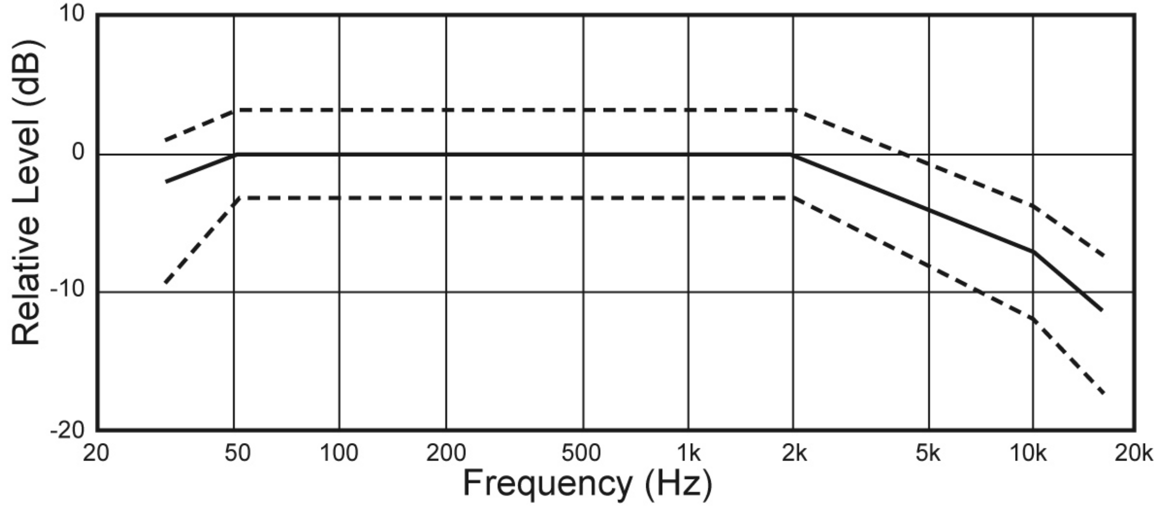
TRUE ✔ or FALSE ✖

The movie industry has standardized sound quality in cinemas and film production facilities.

TRUE: the industry goes through the motions of calibrating these facilities.

But FALSE because the process is so flawed that sound quality varies substantially from location to location – there is no effective standardization.

How well are the "pros" doing?



The X-curve steady-state room curve target for cinemas and dubbing stages as defined in:

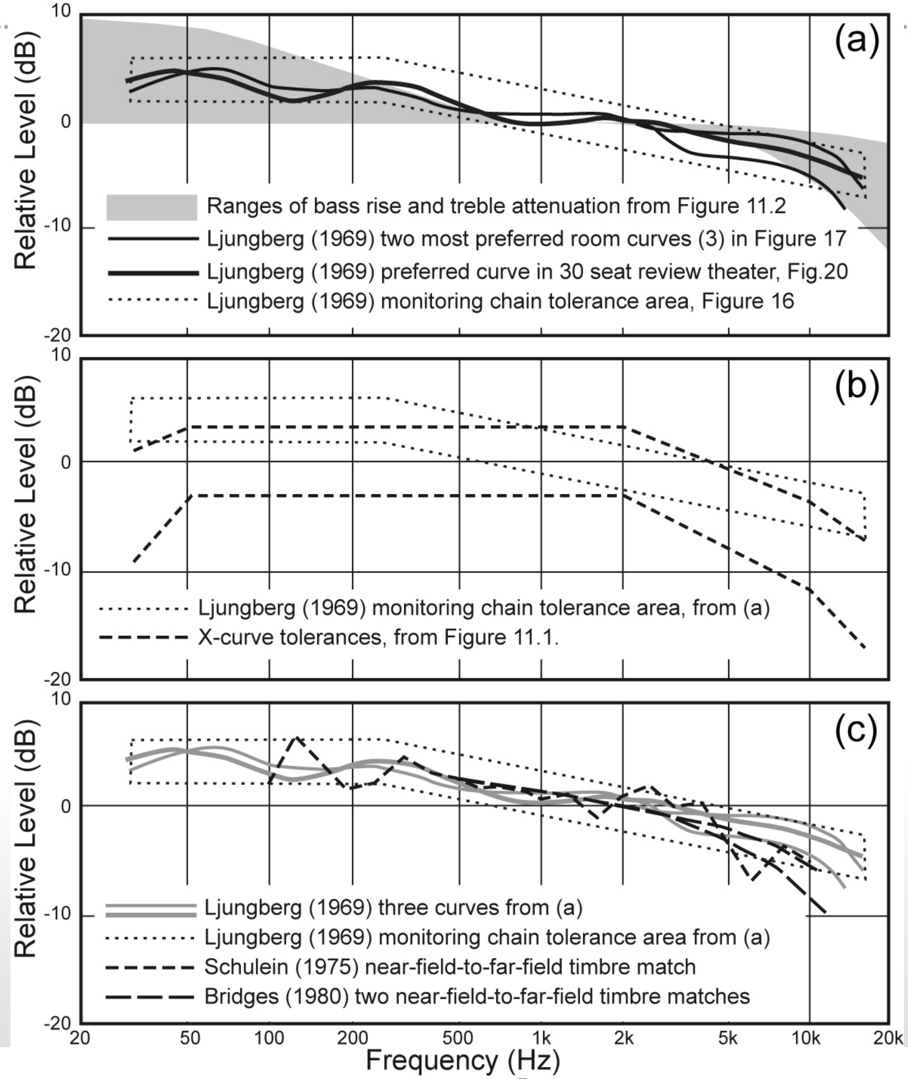
SMPTE ST 202 (2010)

Why is there a high-frequency rolloff?

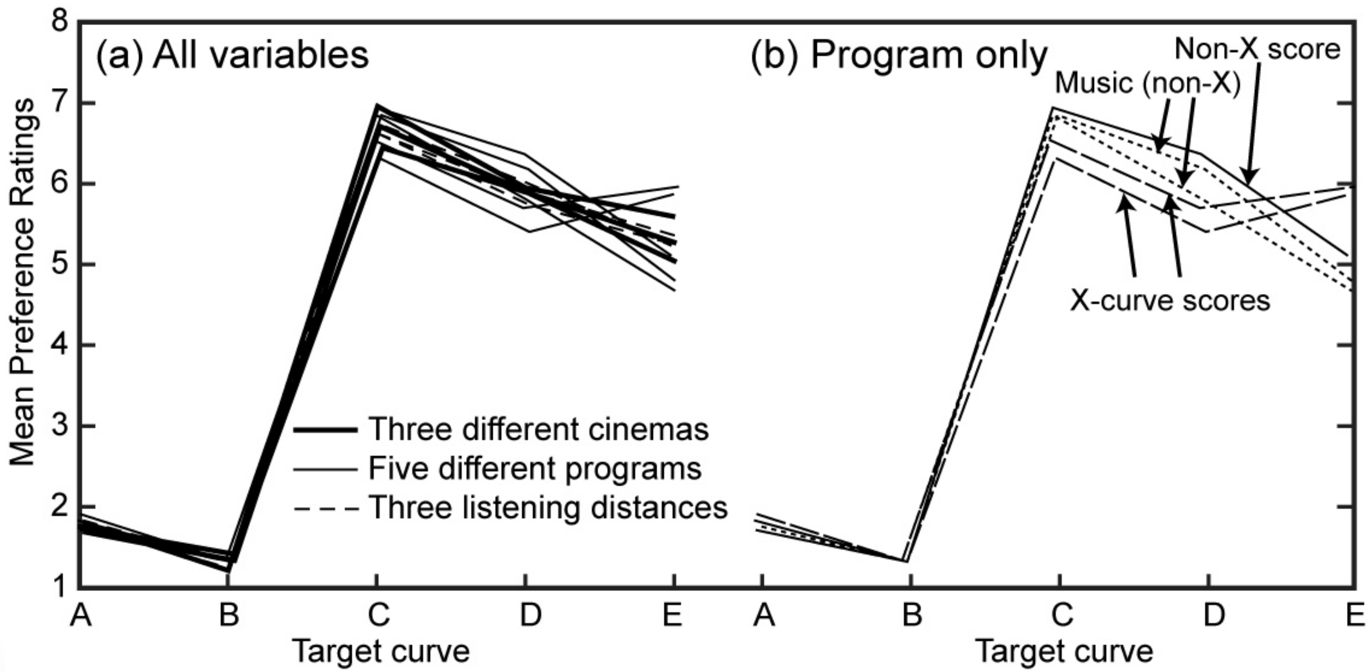
Why is the curve flat below 2 kHz?

Tests done in 1971-72 using loudspeakers, rooms and program material of the day.

Other experiments yielded other results:



Listeners knew what they liked



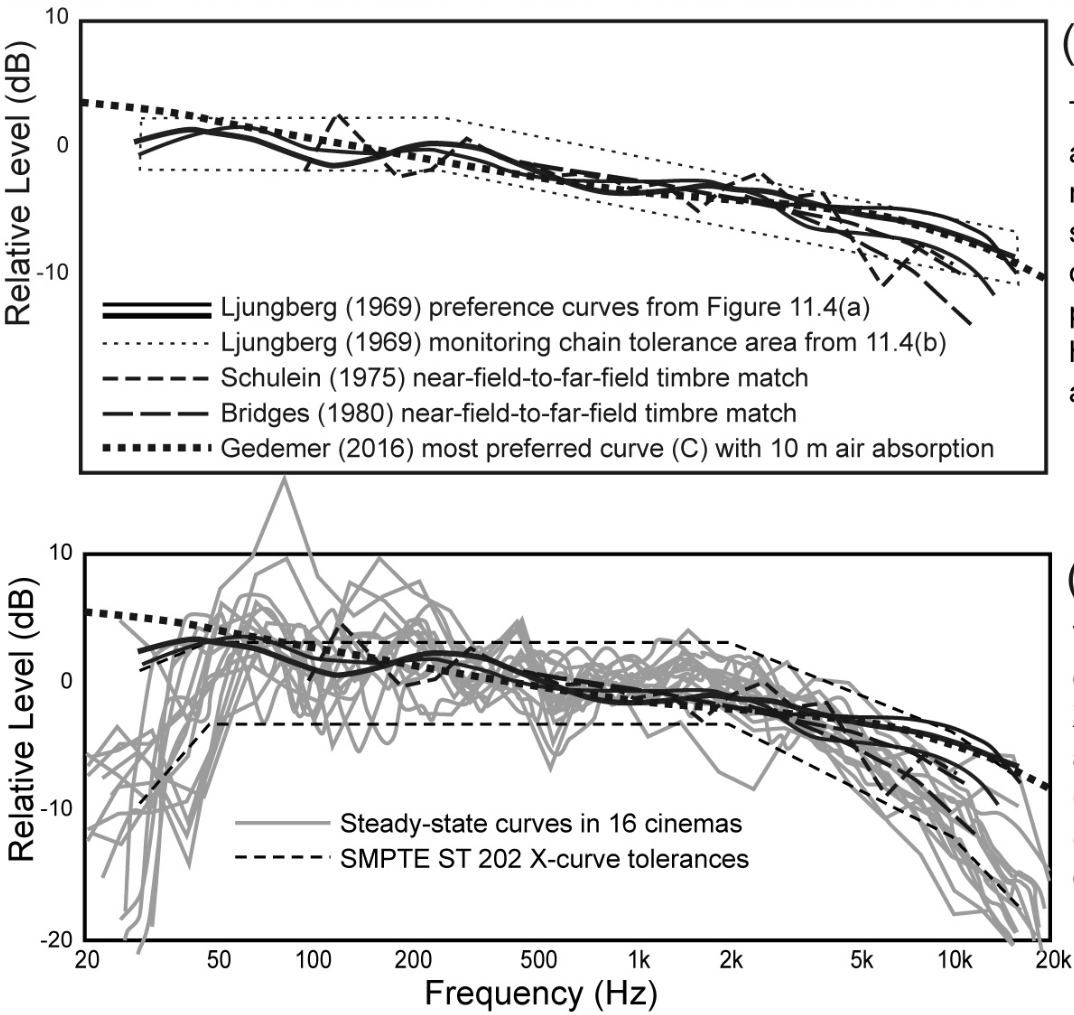
The experimental variables:

Screening room A: 60 seats, RT 0.26 s
Screening room B: 161 seats, RT 0.44 s
Screening room C: 516 seats, RT 0.36 s

Orchestral score mixed in non-X-curve room
Same orchestral score mixed in X-curve room
Film score mixed in X-curve room
Steely Dan “Cousin Dupree”
Toy Matinee “Last Plane Out”

Seated in second row from front
Seated at 2/3-distance from screen to rear wall
Seated in second row from rear

Interesting comparisons:



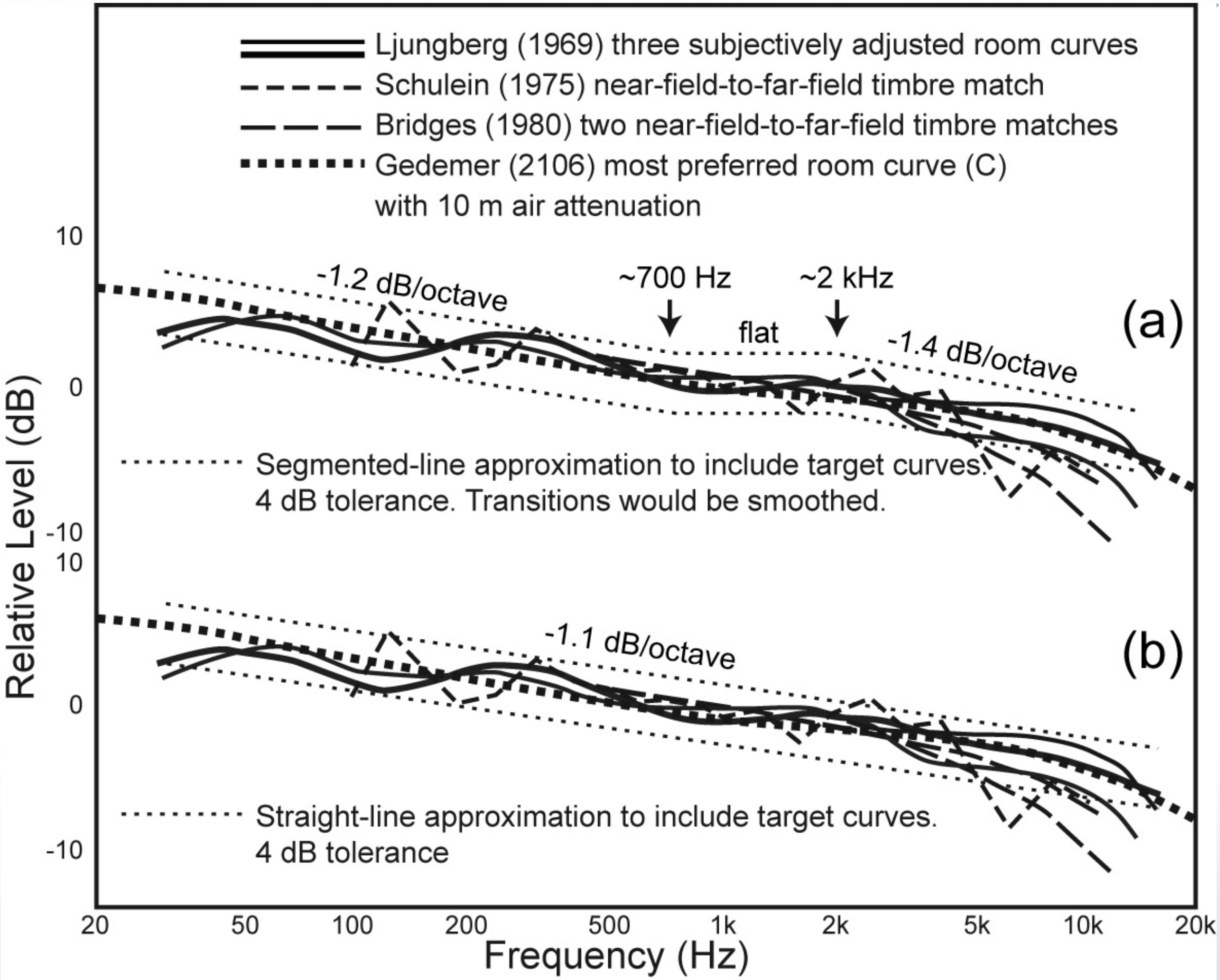
(a)

The results of three timbre-preference and two near-field-to-far-field timbre matching experiments. All are shown superimposed on the tolerance area for octave-band filtered measurements published by Ljungberg (1969) which he proposed August 19, 1967 - 50 years ago!

(b)

The curves shown in (a) superimposed on full-bandwidth measurements in16 X-curve calibrated cinemas. The curves are from Figures 10, 16 and 17 in Toole (2015) using data from Holman (2007), SMPTE TC-25CSS (2014), and Newell et al. (2010).

Possible new target room curves:



The real target is flat on-axis/listening window = flat direct sound

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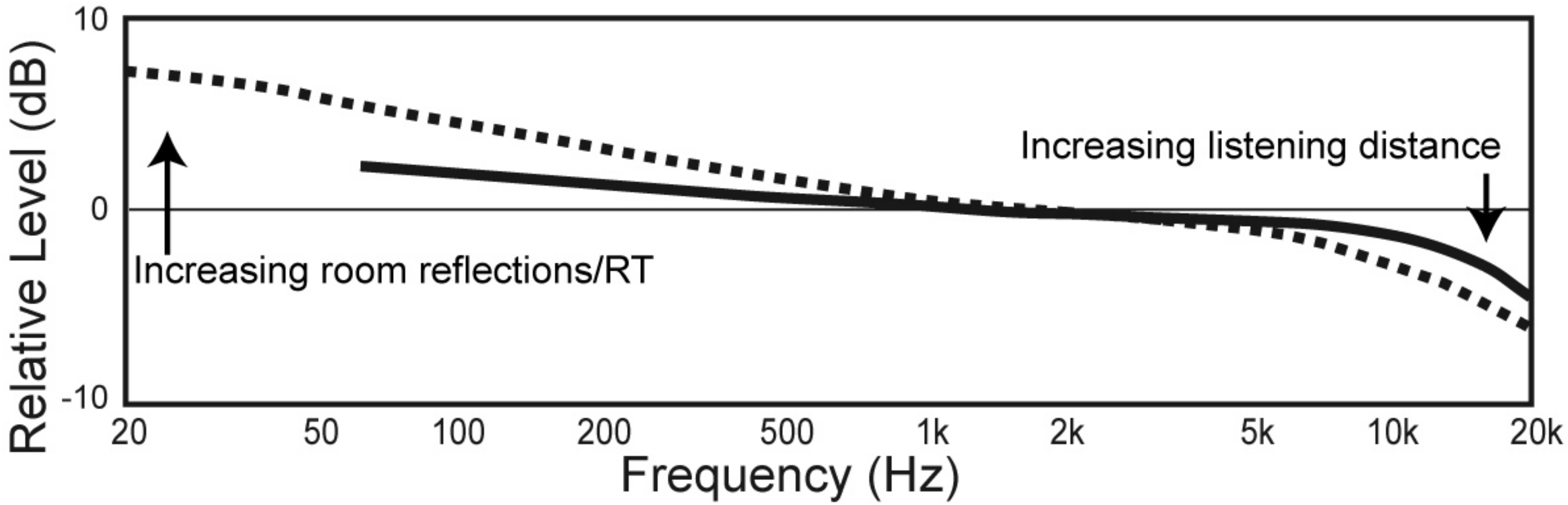

Subjectively preferred steady-state room curve in three professional screening rooms: 60, 161 & 516 seats, mid-frequency RT: 0.26, 0.44 & 0.36 s. From Figure 11.5(c) and Gedemer (2016). 10 m of air attenuation is included.

Idealized steady-state room curve for subjectively preferred domestic and monitor loudspeakers in typical home listening rooms and home theaters: mid-frequency RT: 0.3 to 0.4 s. 3 m of air attenuation is included. From Figure 12.4(d).

A good loudspeaker works anywhere: 6 to 516 seats!

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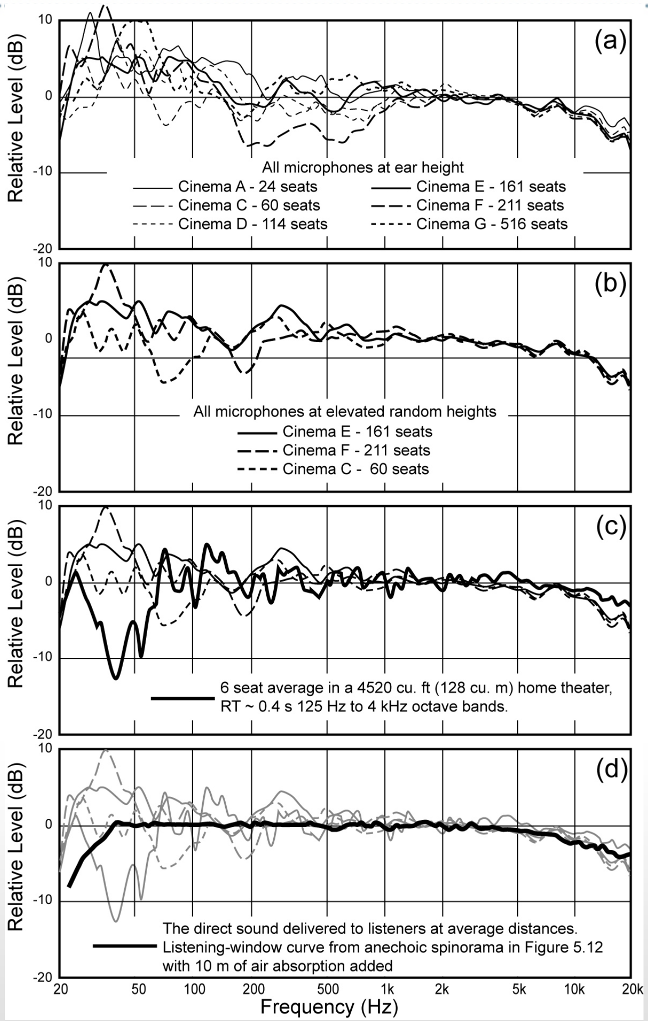

The lessons:

1. Start with a good loudspeaker: anechoically flat on axis with a uniform directivity index (DI).
2. Do not put microphones close to seats, and not at all at the same height. The ear location is NOT special.
3. Above about 400 Hz it is probably best not to pay attention to the room curve, and if equalization is attempted it is possible to degrade the performance of good loudspeakers.
4. At low frequencies start with multiple subwoofers, preferably SFM, and then use equalization.

Audio Folklore

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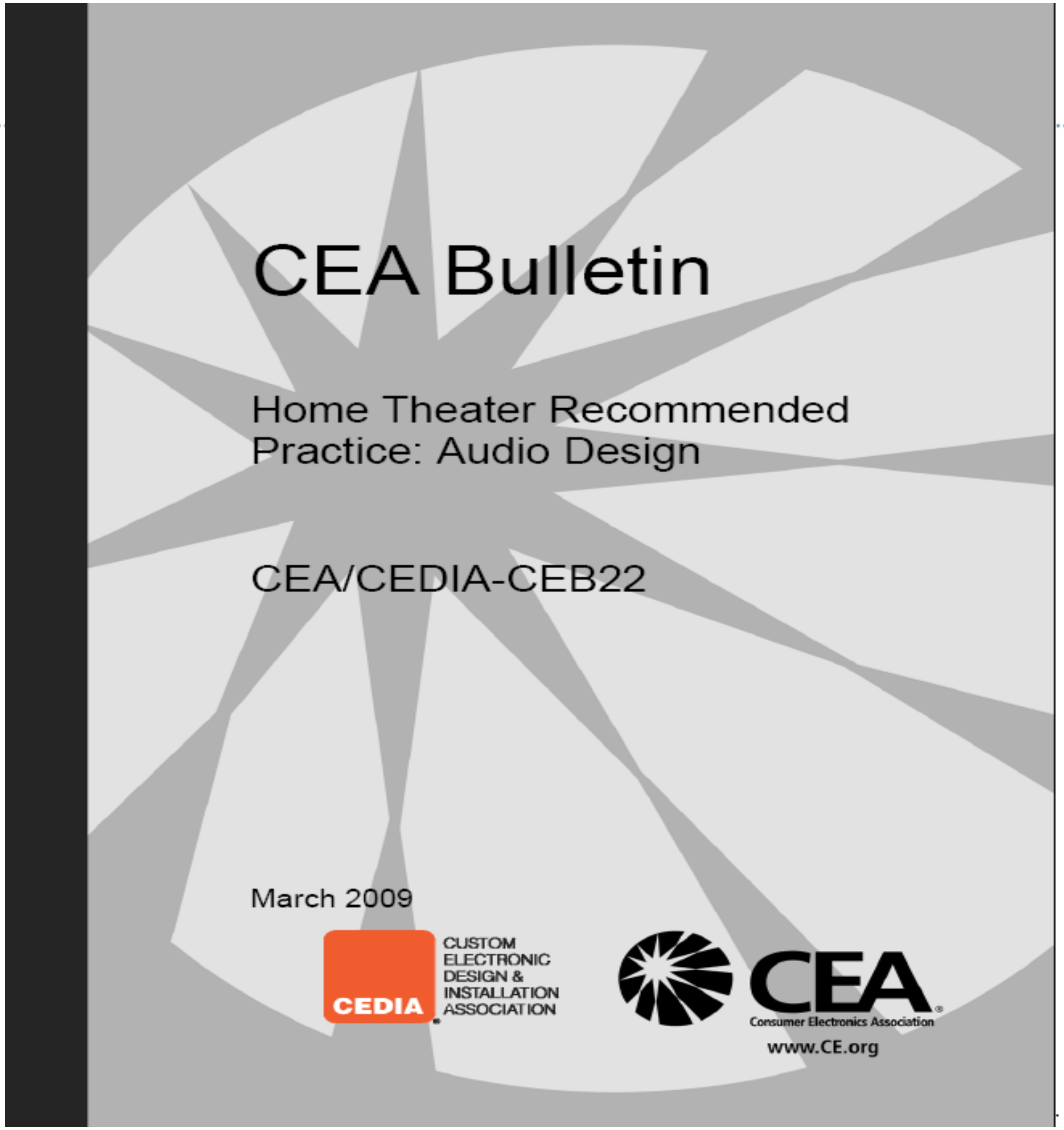
It is sometimes said that home theaters should emulate what is heard in film dubbing stages.

- I hope not!
- In terms of sound quality we can do MUCH better than that!

HARMAN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March 2009

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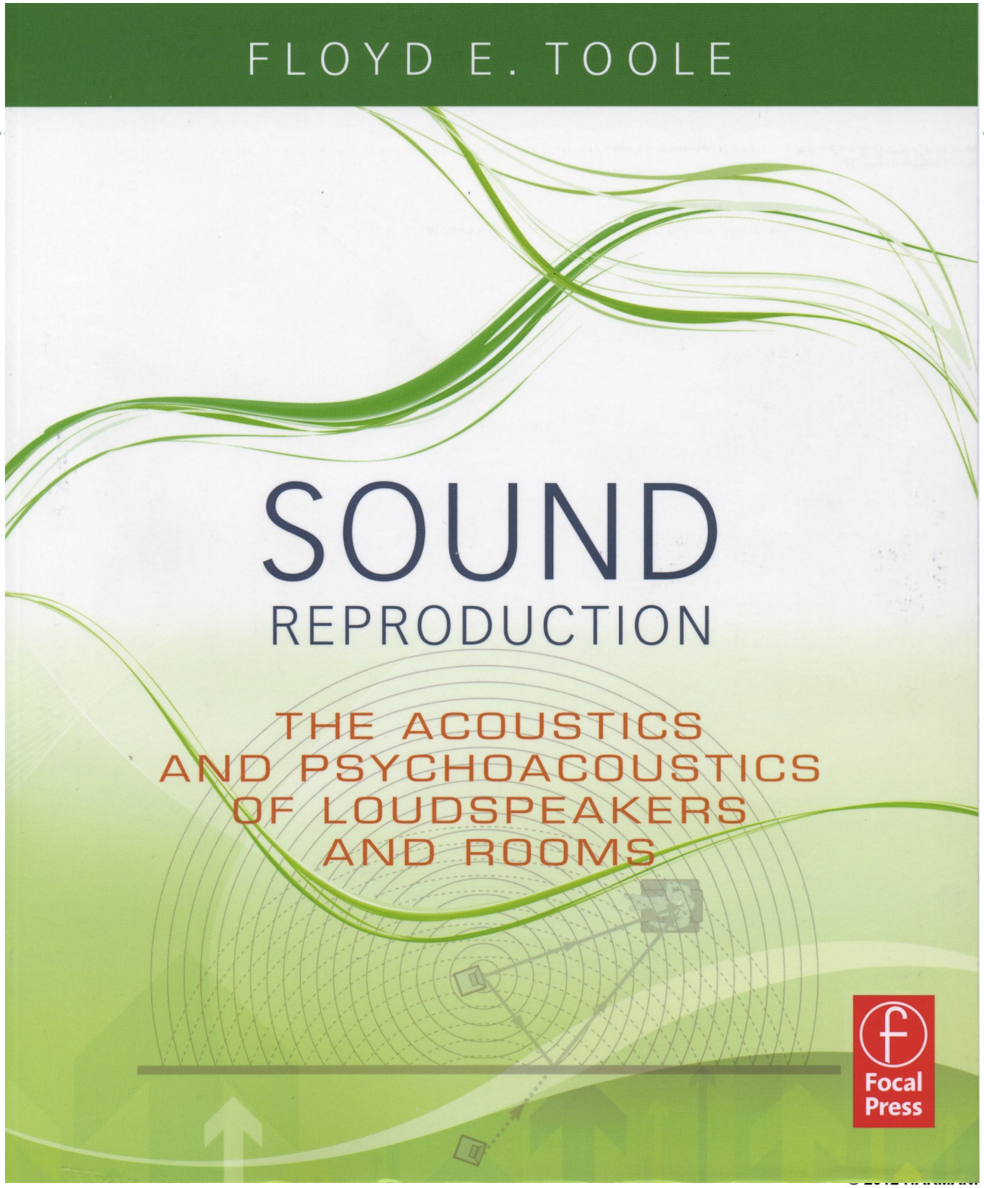
Good guidance



More
Good guidance

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WHERE SOUND MATTERS