Forum Acusticum 2011

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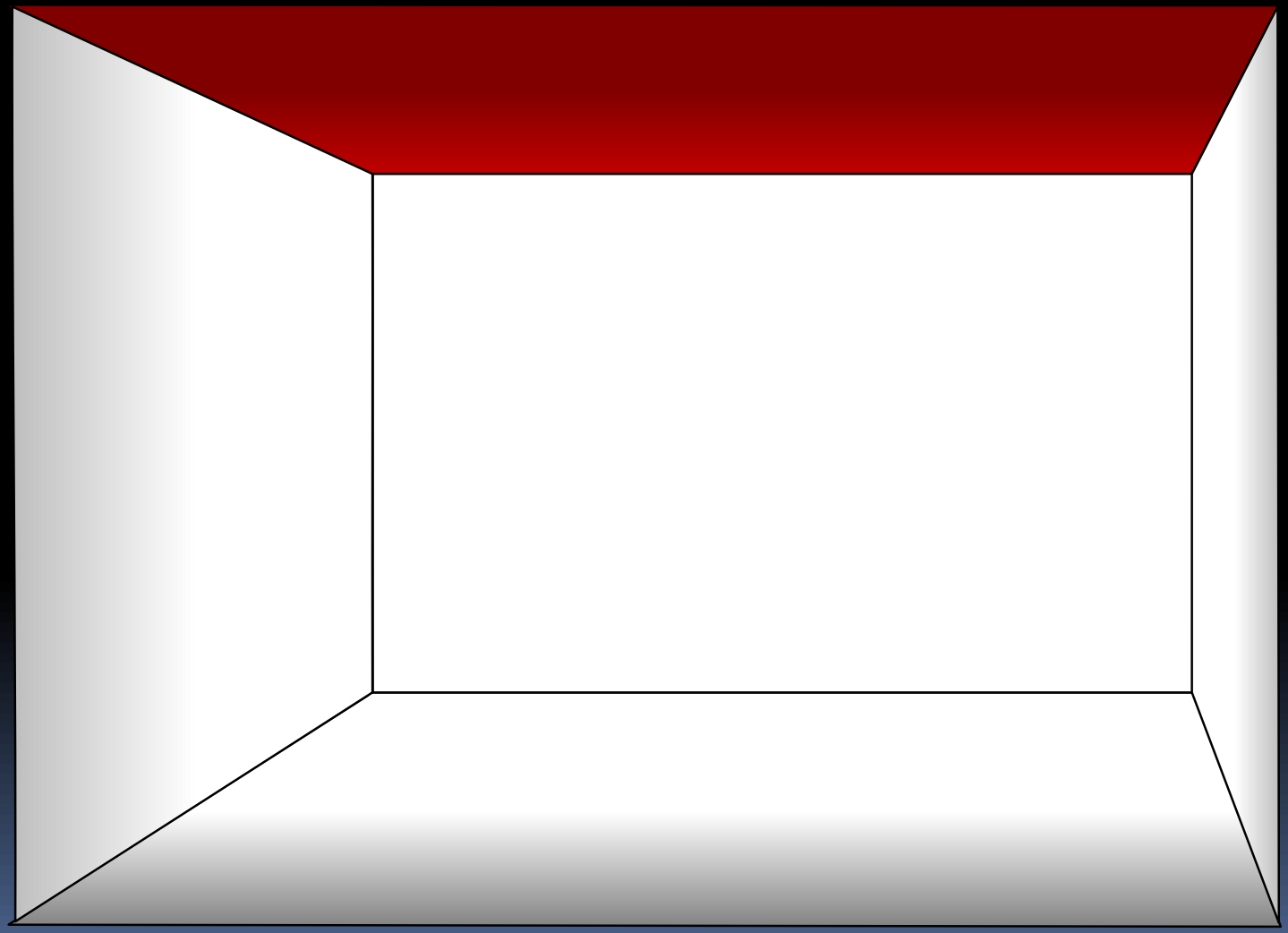
Small room acoustics

THE HARD CASE

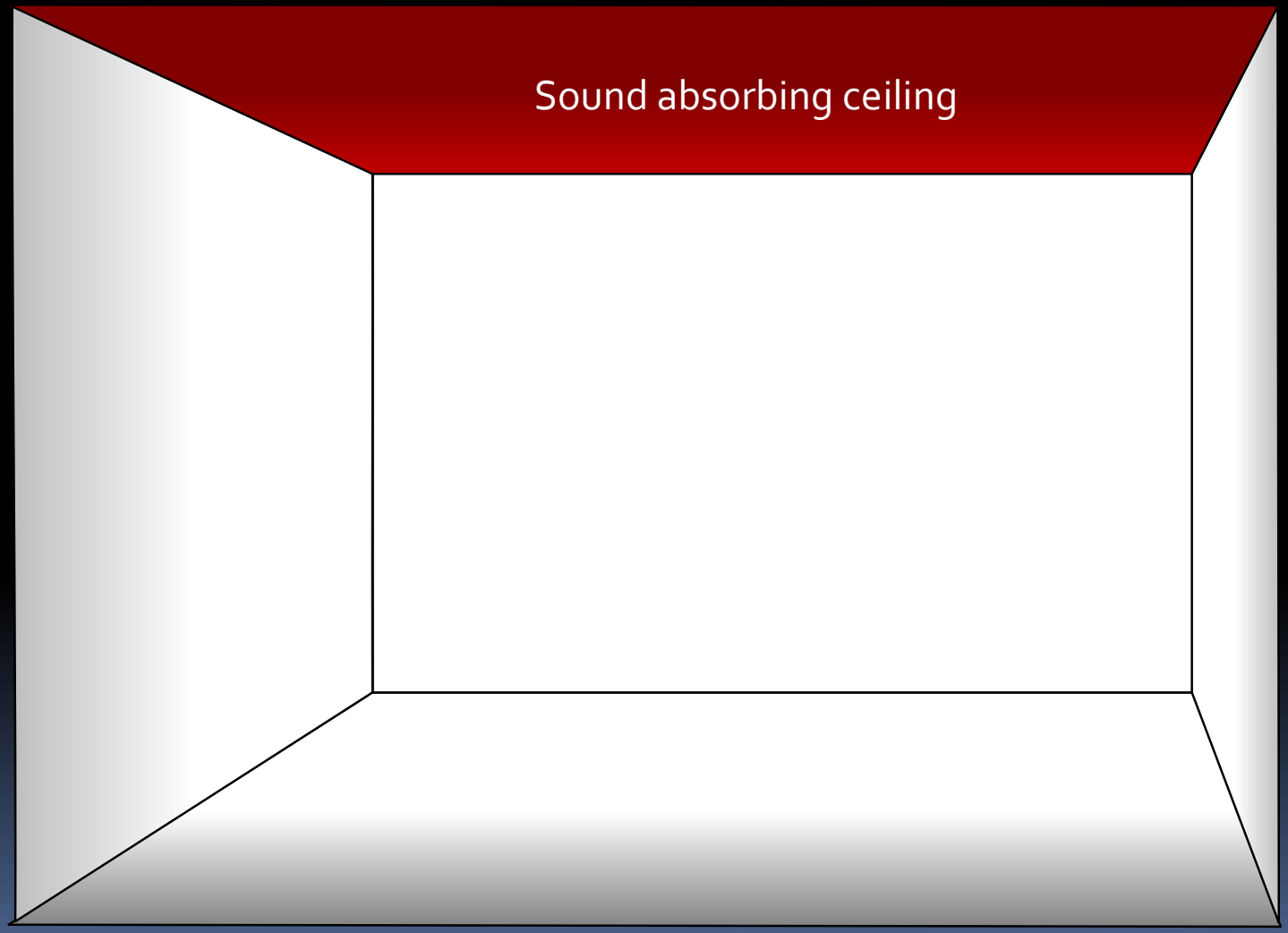
The Hard Case

- Cuboid room, dimensions given, take it or leave it
- Hard walls
- Hard floor
- Soft material elements not wanted
- Ceiling – the only possible absorbing surface
- Sources with harmonic spectra
  - Speech, music, media playback, etc

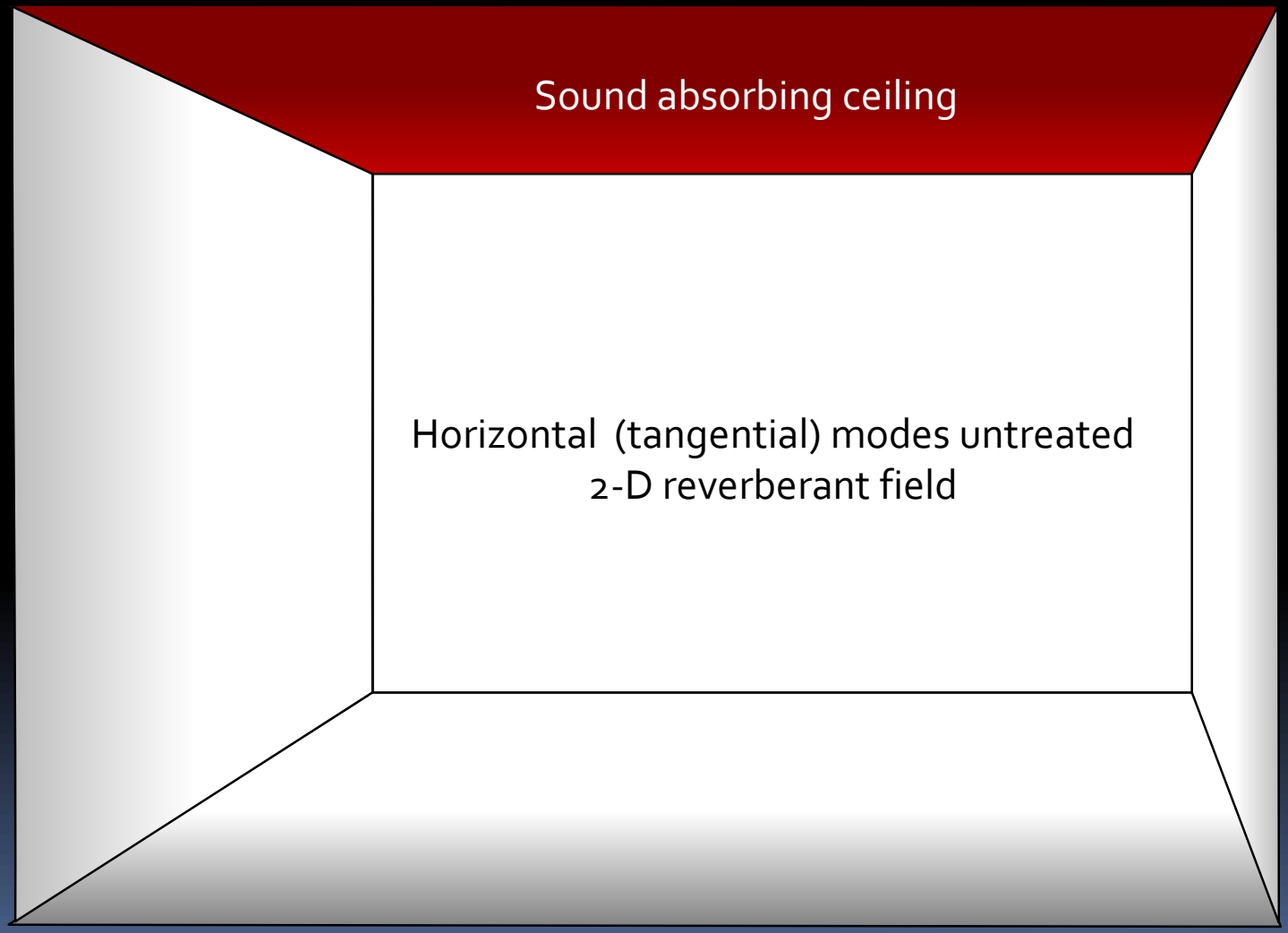
The Hard Case



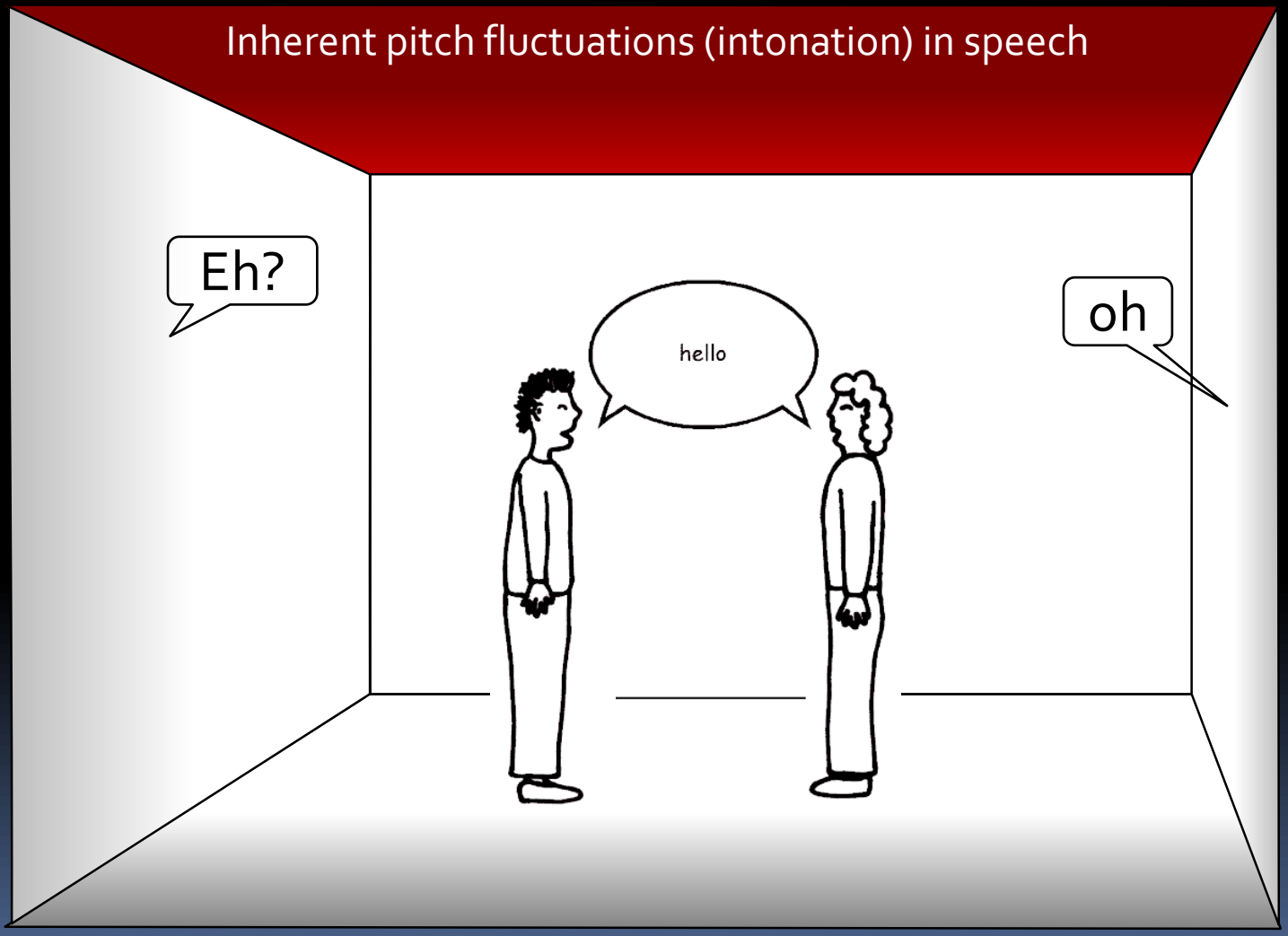
The Hard Case



The Hard Case

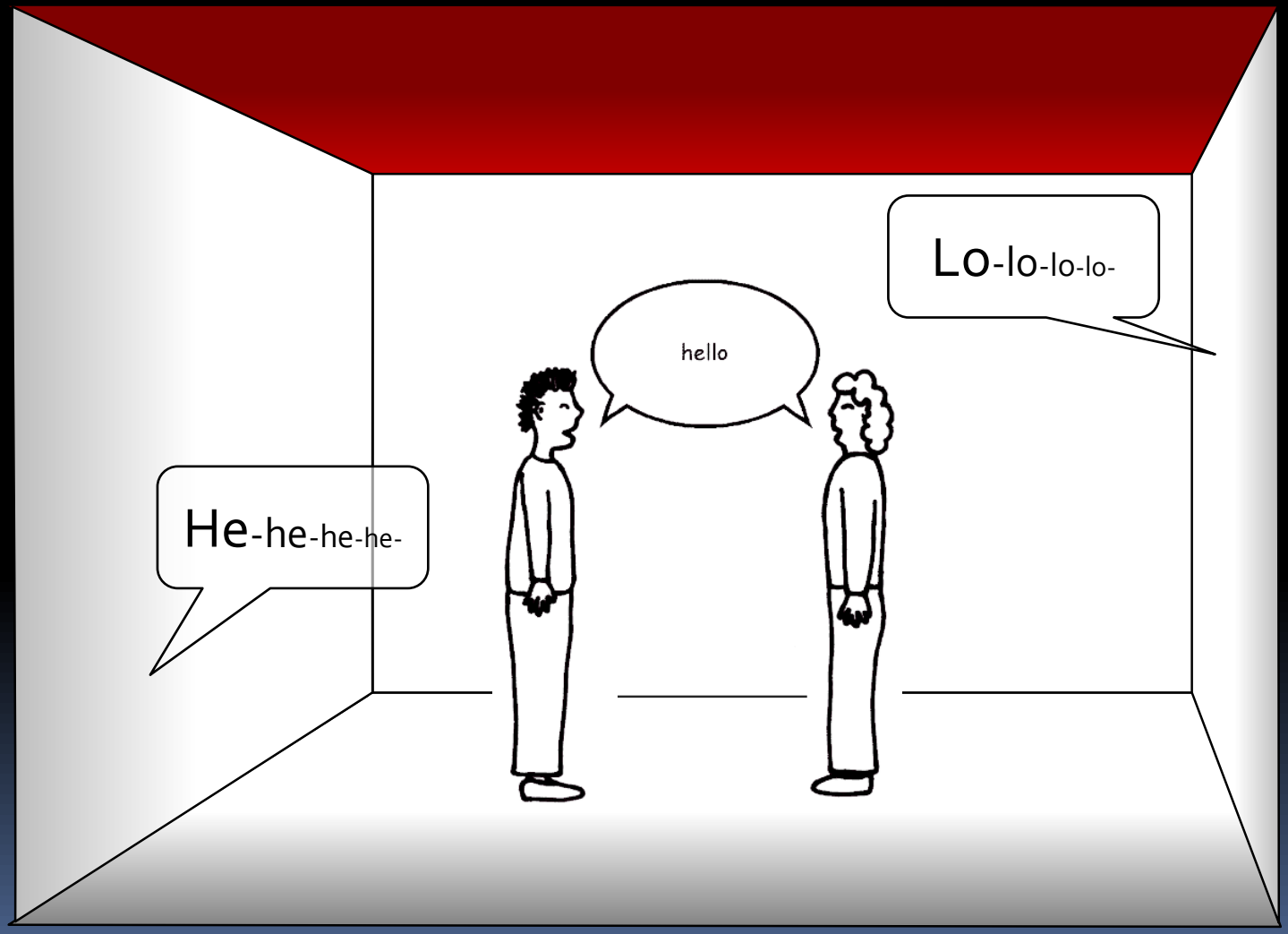


Disturbing speech response



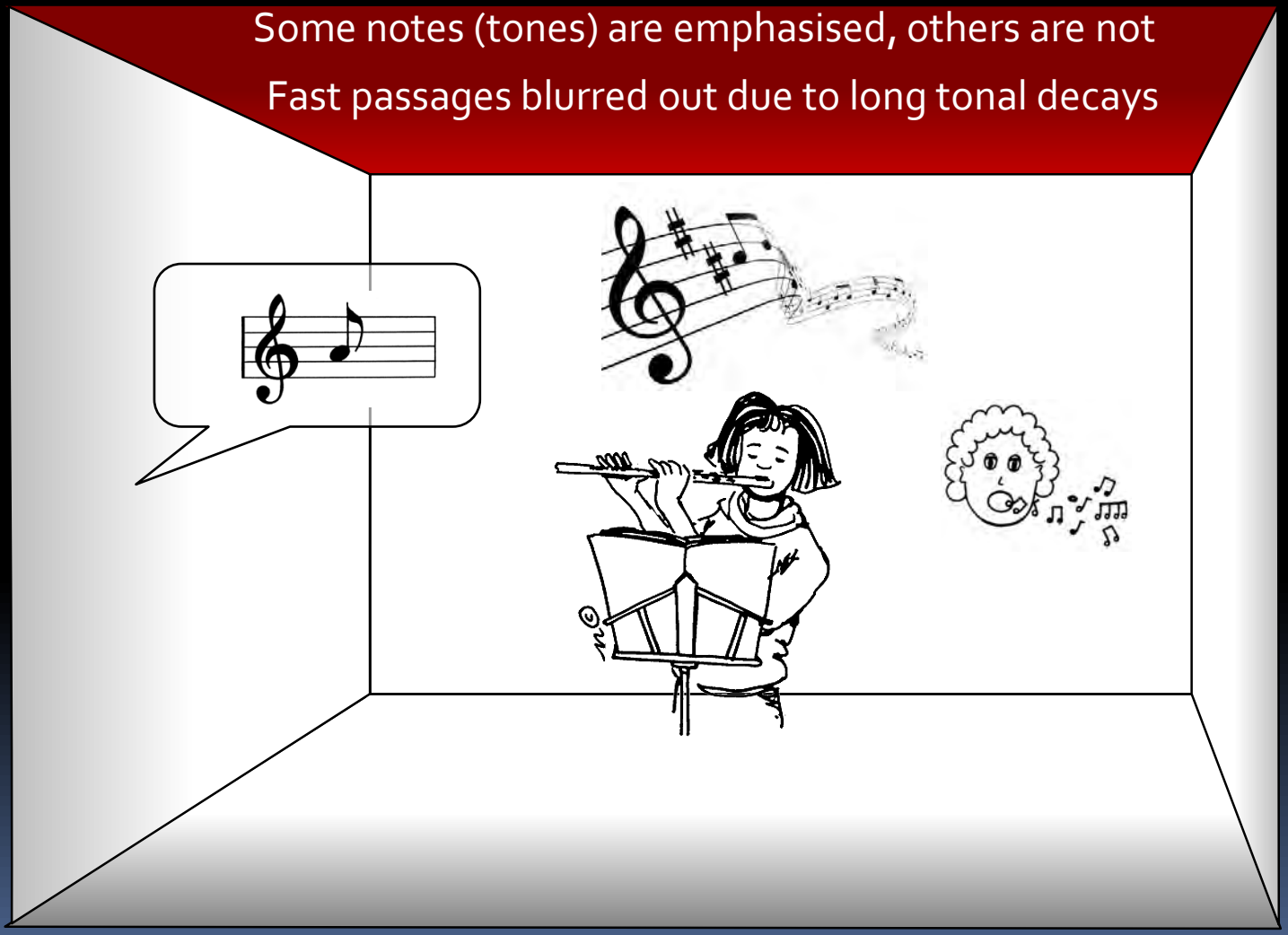
Pitch fluctuation in various positions reveals uneven vowel response

Flutter-echo



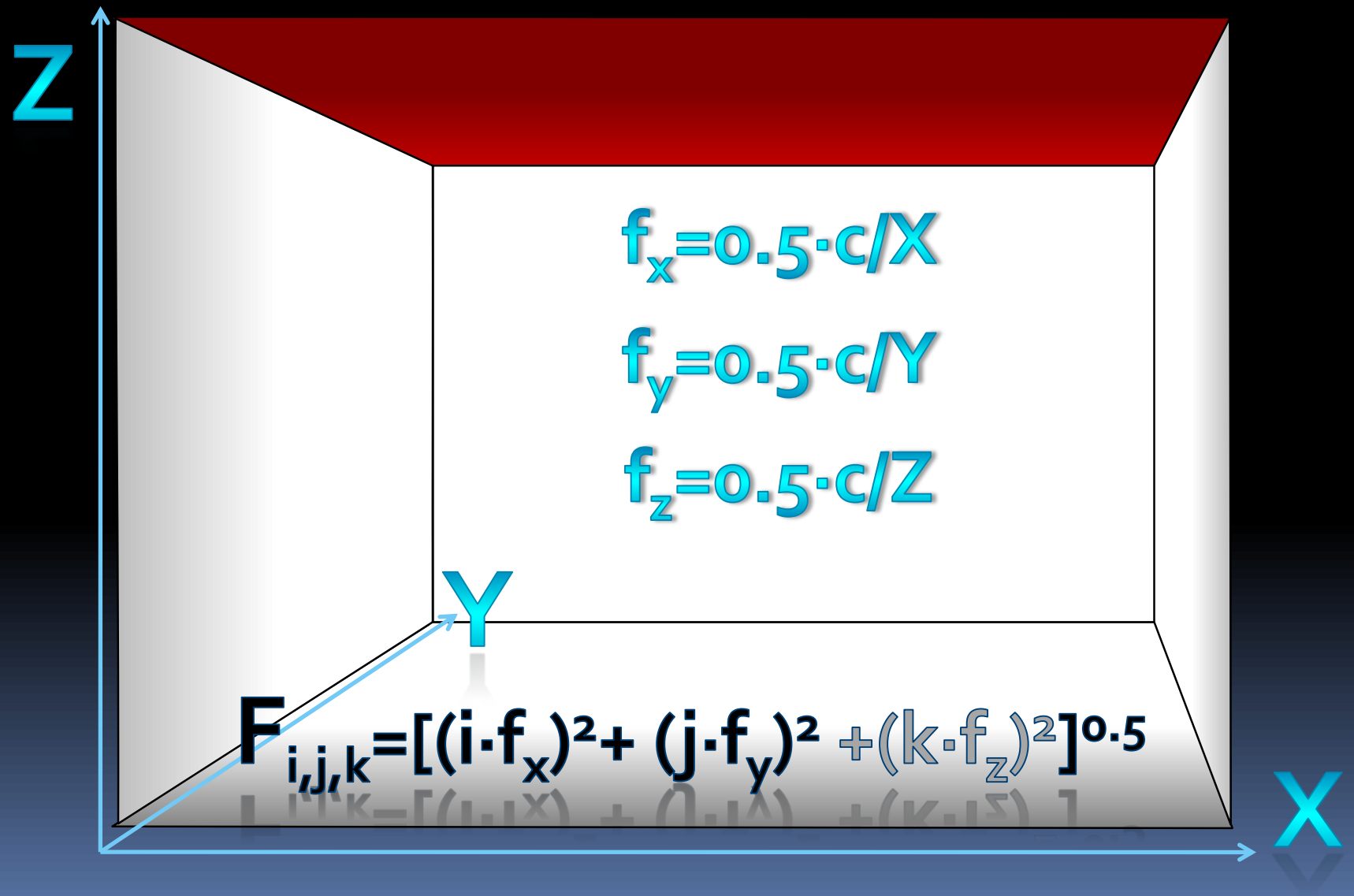
Flutter echo is a temporal feature of a complex mode, thus accompanied by tones

Discriminating pitch response

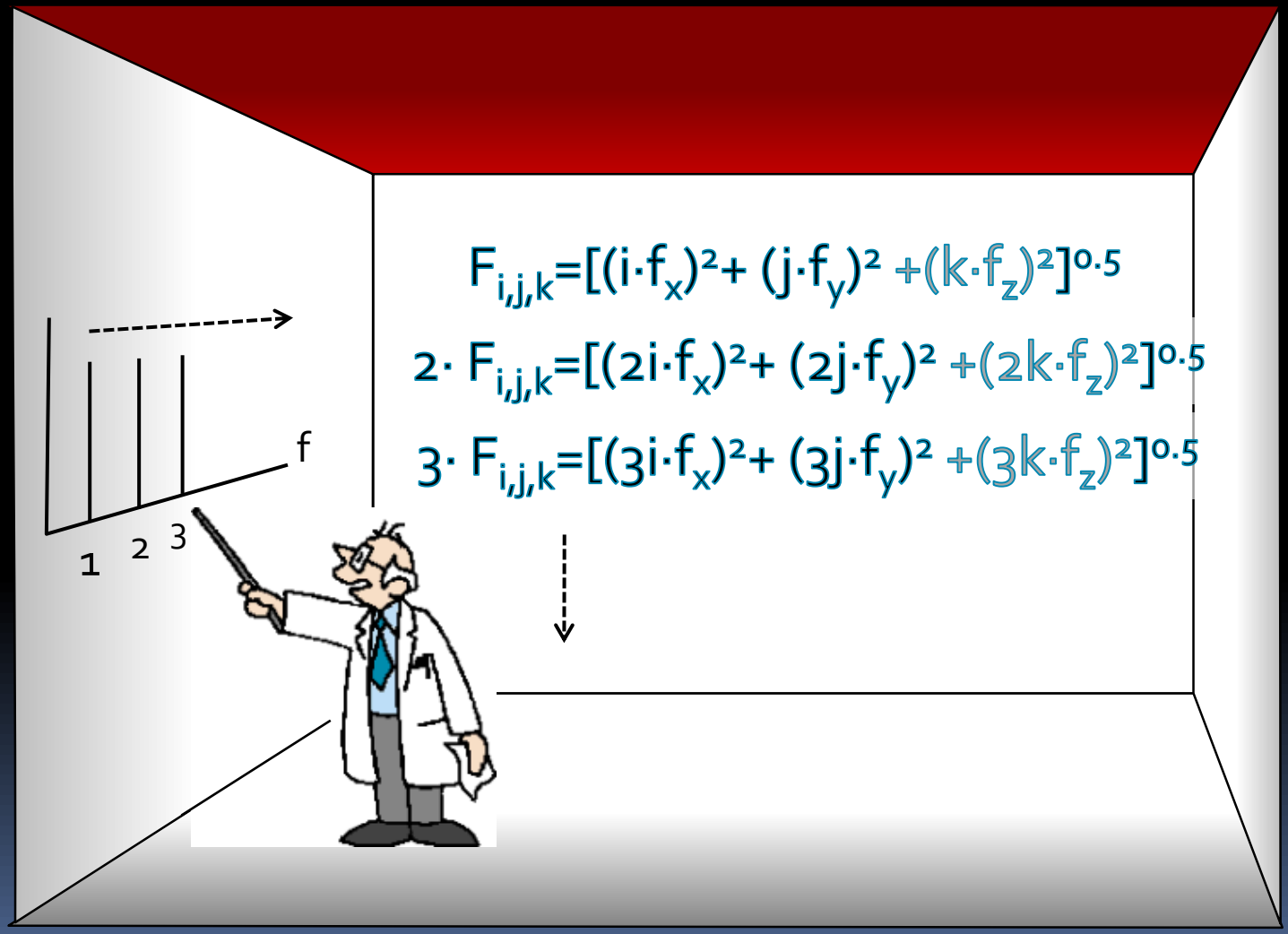


Intonation can be HARD, since room-modes often are “out-of-key”

Hard Case fundamental modes

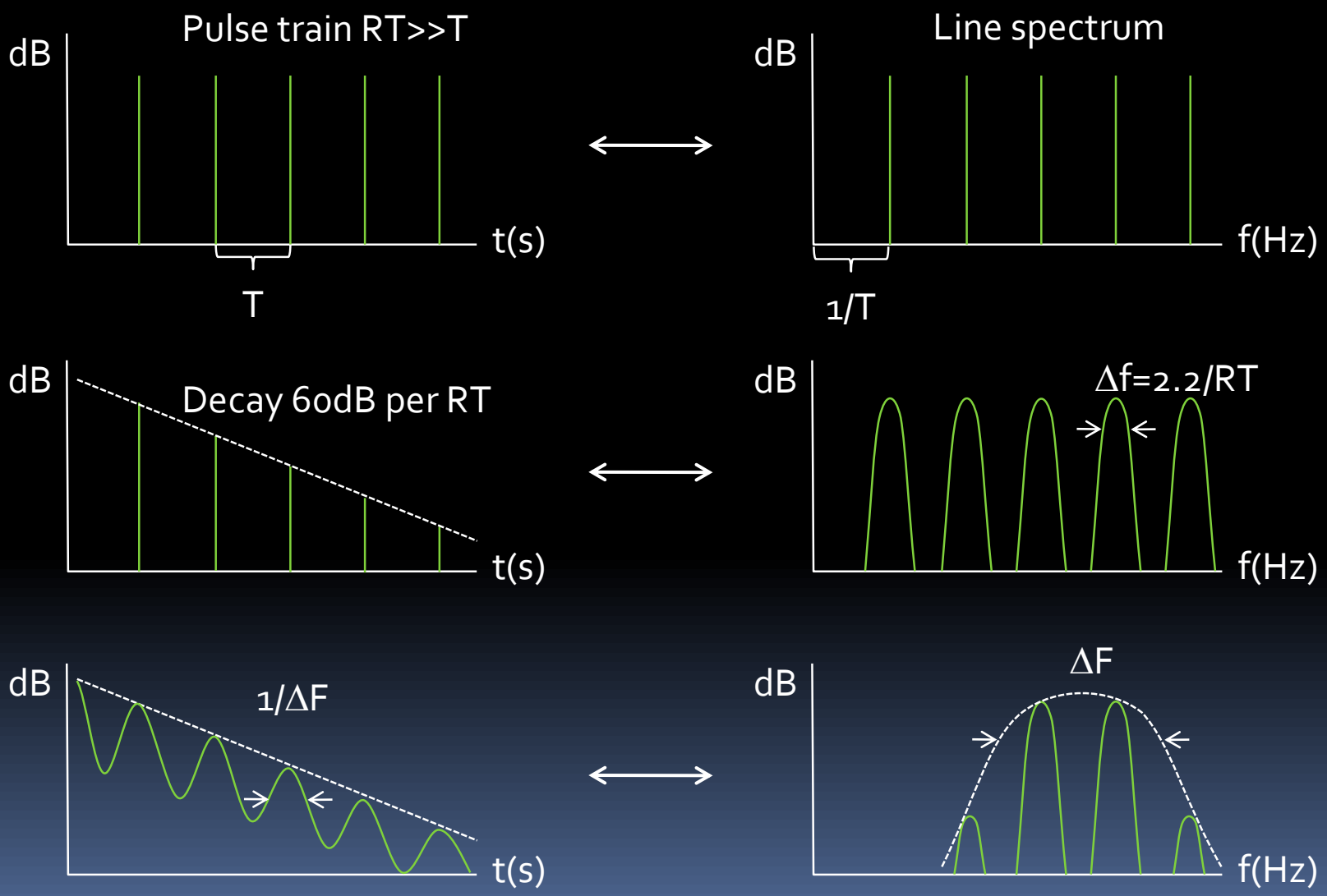


Hard Case harmonic modes

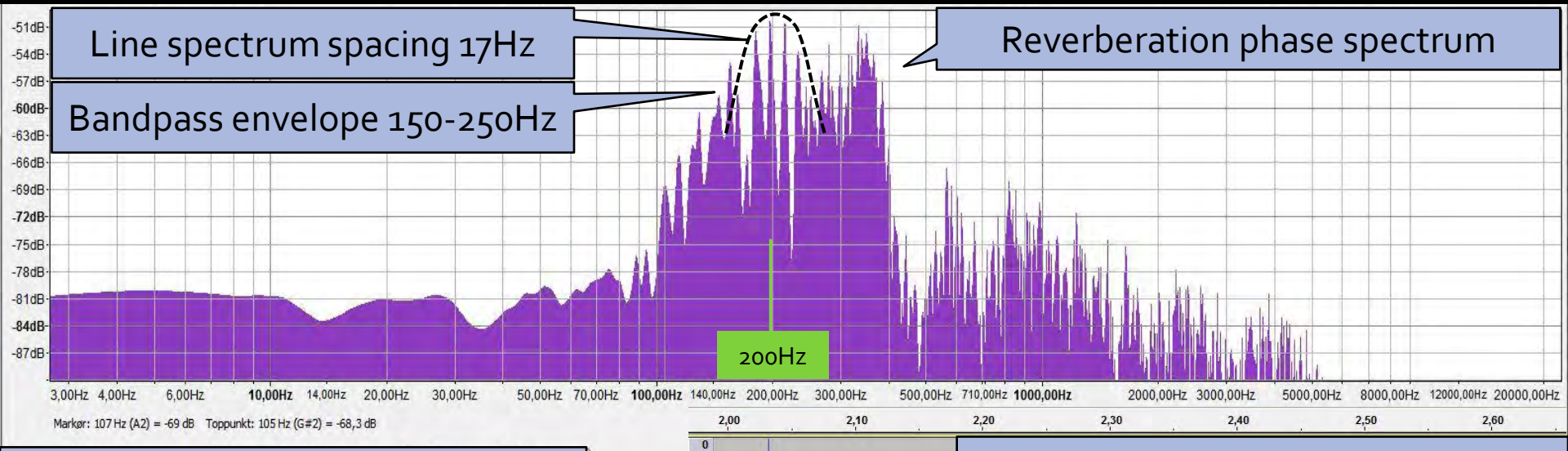


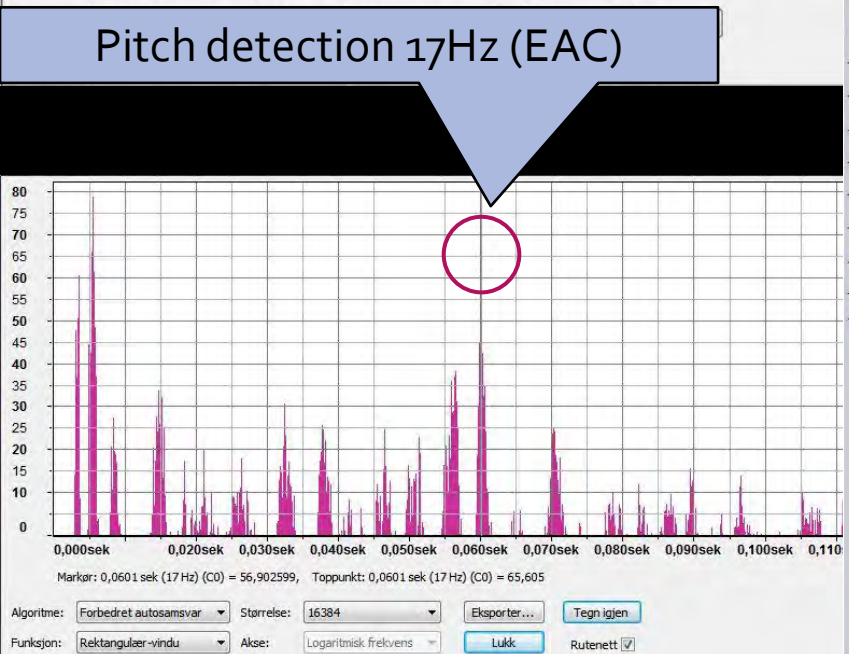
ANY cuboid mode = the fundamental of a harmonic spectrum -> Pitch

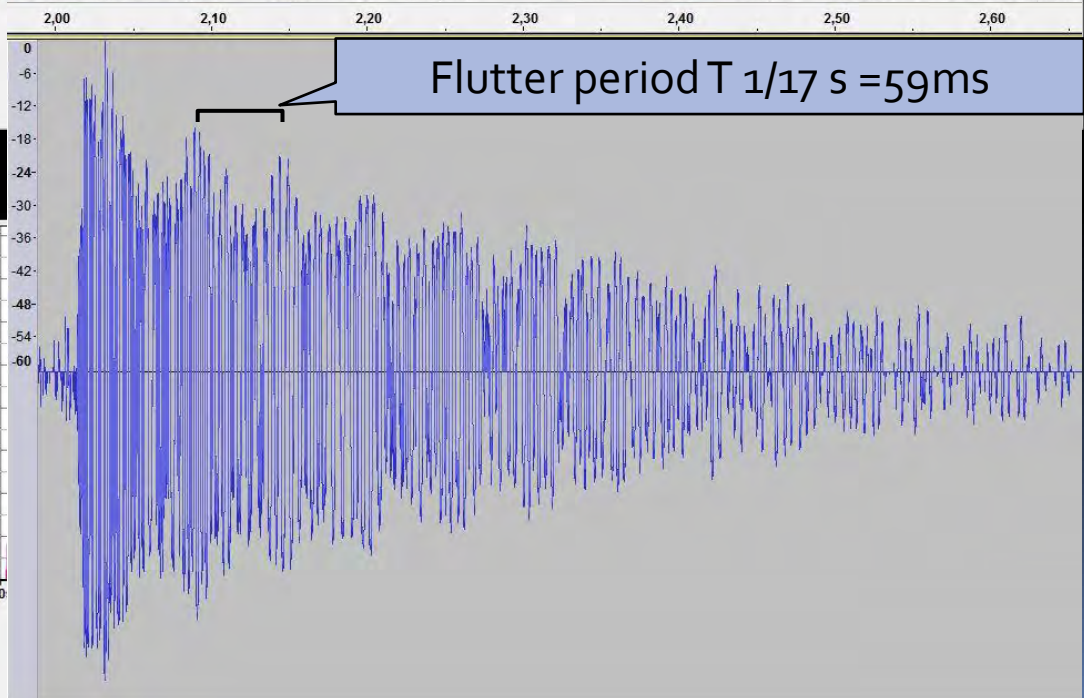
Periodic response, period T



Periodic response measured







Cuboid acoustic highlights

- Any cubiod mode $F_{i,j,k}$ defines a periodic response with period $T=1/F_{i,j,k}$
- Complex mode = the harmonic series of modes with fundamental frequency $F_{i,j,k} = 1/T$
- Periodic room response can be perceived as Pitch response
- Supported pitch (musical notes) are defined by the harmonic series 1/T, 2/T, …
- Flutter-echo of period T is the temporal percetion of a harmonic series with spectral spacing 1/T and at least two audible components
- Audible effect above the Schroeder limit, too

The Hard Case is very common

- Many rooms are used for speech
- Music may be less common, but more sensitive
- Minimalistic interior styles
- Carpets often unwanted or forbidden
- Acoustic wall-treatment conflict with furniture, fixtures, aesthetics or economy
- Cubiod geometry is encouraged by gravity and the tempting simplicity of right angles

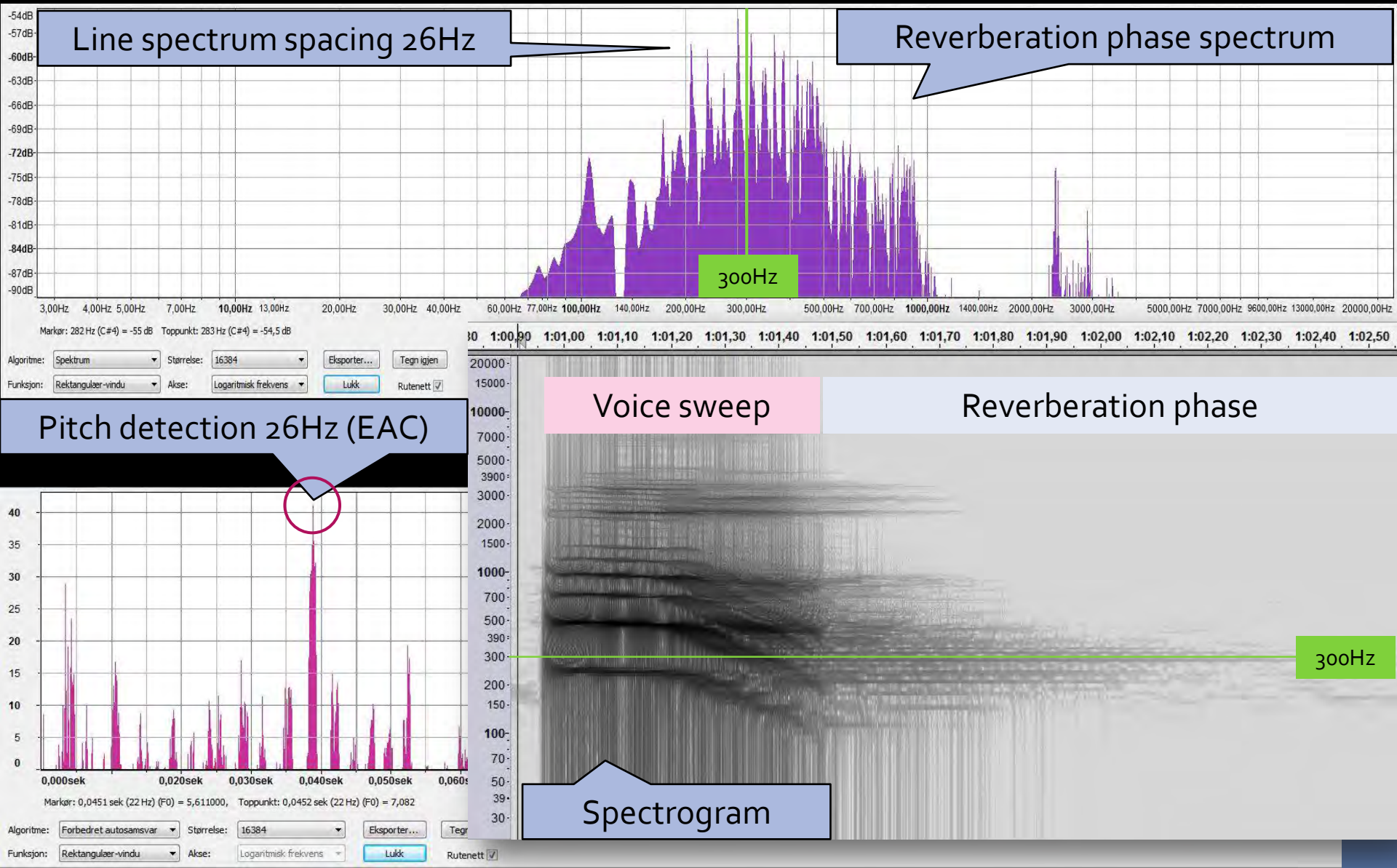
Hard Case Tonal Response

- Cuboids' respond to the PITCH of vowels and musical tones
- Human perception sensitive to pitch, pitch draws attention
- Problem easy to perceive, but…
- Hard to measure with blind methods
- Hard to predict (slanted walls makes prediction harder)
- Hard to avoid
- Hard to accept
- Hard to handle
  - Smallest dimension of hard treatment > $\lambda/4$
  - It takes >50cm thickness to control response down to 170Hz (E3)
  - Horizontal modes ignores ceiling absorbers

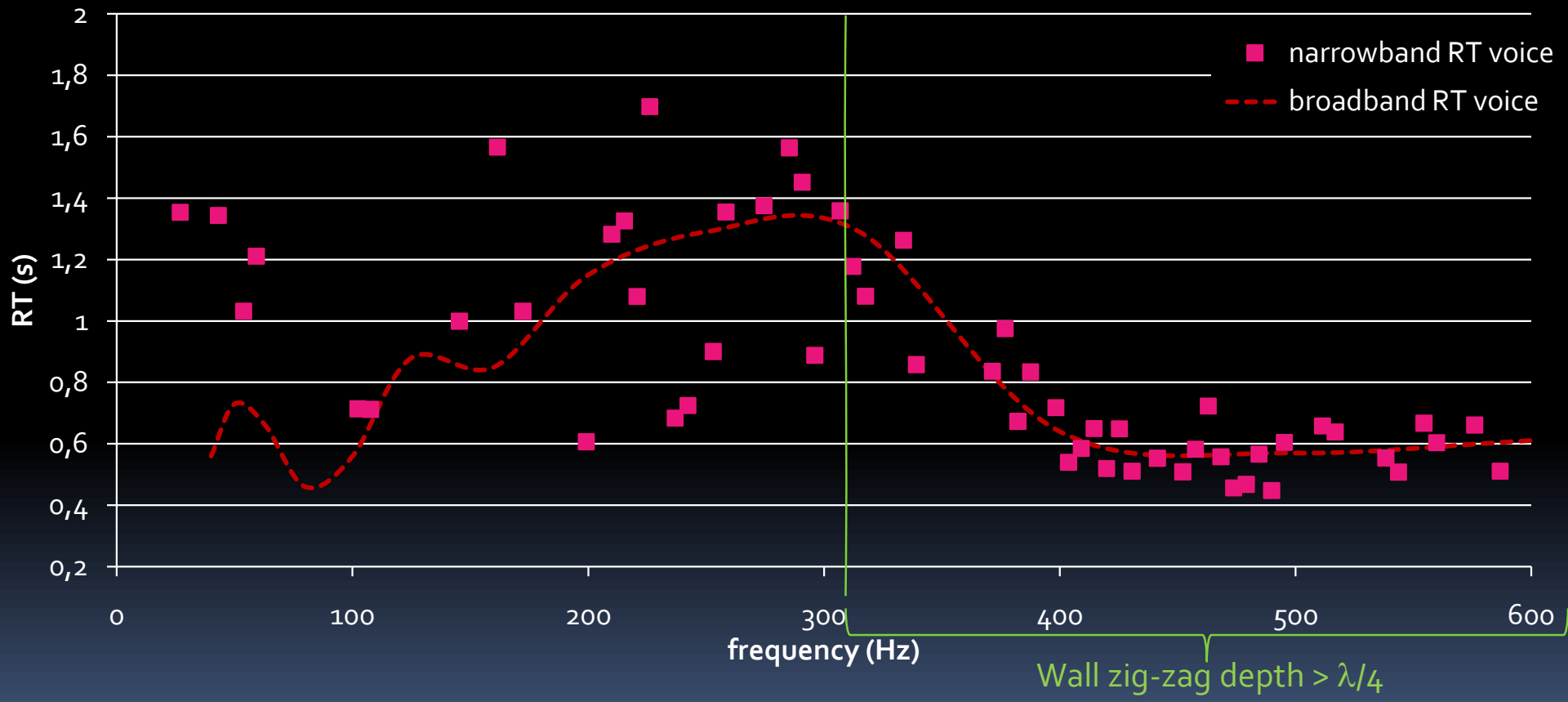
Measurement case

- Parallel walls 6.5m apart (26Hz)
- One wall 28cm deep zig-zag shape (=λ/4 at 300Hz)
- Schroeder region above 125Hz
- Disturbing voice response heard in the 150-300Hz range
- …together with a flutter-echo
- Hard to detect with blind measurement

Measured voice response

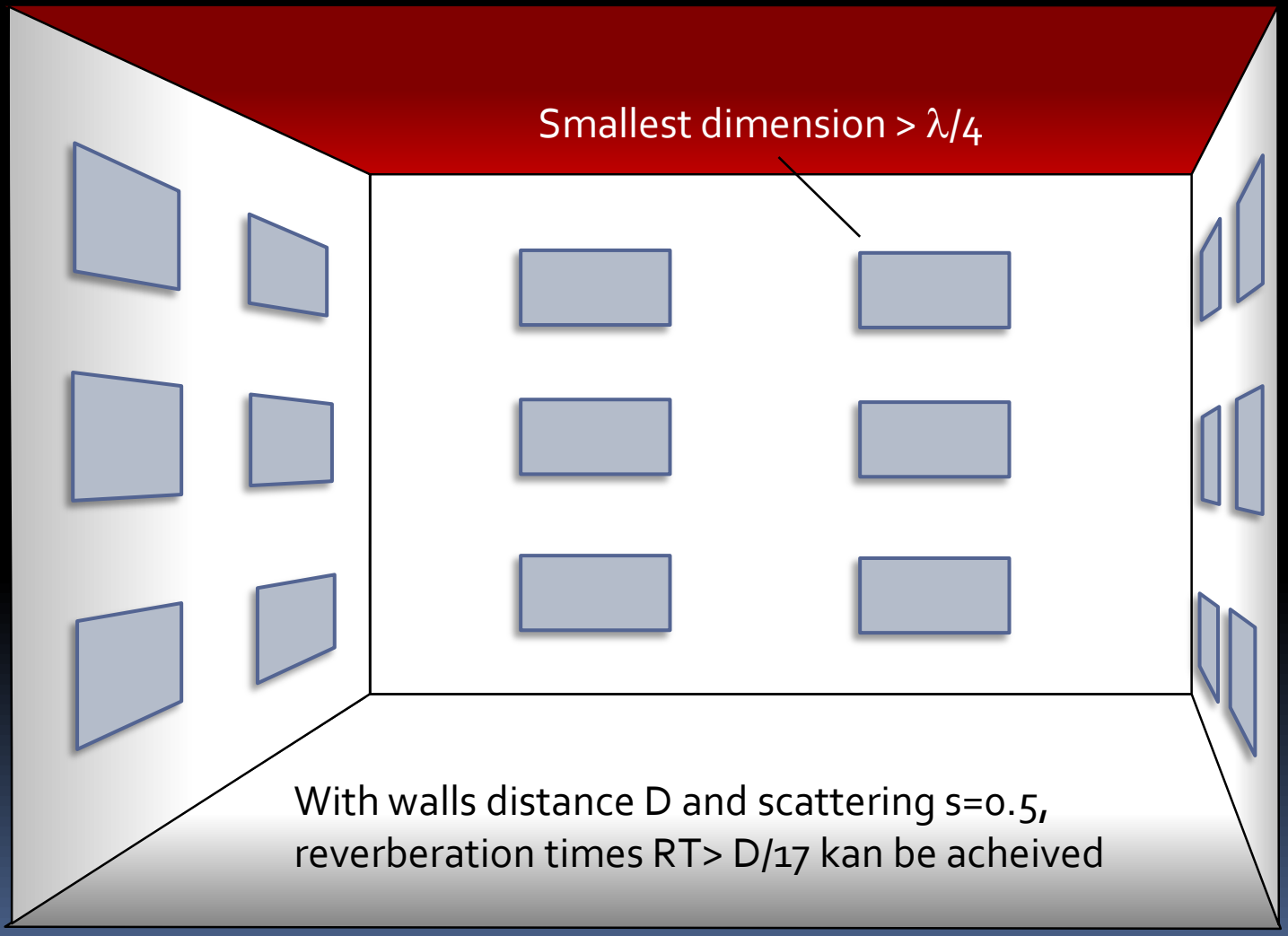


Decays in 5.3Hz narrowband vs 1/3 oct broadband, RT(s)



Narrowband decay deviates normal-distributed from broadband decay: σ=26%

Softening the Hard Case



Element density depends on wall-to-wall distance and RT requirement.

Conclusions

- Hard case cuboids respond strongly and unevenly to speech and music, due to coinciding harmonic spectra
- Walls should be treated with sound scattering elements
- Obtainable RT's depend on longest wall-to-wall distance D, and the scattering coefficient
- RT's down to D/17 can be obtained
- Treatment thickness > $\lambda/4$ in problem range, e.g. 50cm at 170Hz
- Audibility is more than loudness; Tonal RT is important

Further work

- Narrowband RT distribution to be investigated further
- Lower limit of problem range remains to determine
- Methods for predicting, measuring and assessing Tonal Response in rooms
  - Criteria for music and speech
- More insight in horizontal 2D-acoustics

Thank you

More info?

The www center for search, research and open sources in acoustics

www.akutek.info

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A semi-hard case

- 66m² floor, 3.8m high, ceiling α=0.7
- Schroeder region above 125Hz
- 3 walls with average alfa=0.25
- Hard Zig-zag wall deviates from by 28cm (=λ/4 at 300Hz)
- wall to wall distance 6.5m (mode=26Hz)
- Prolonged narrowband RT's are heard in the 150-300Hz range
- …together with a flutter-echo