

# Rating low-frequency noise in buildings, focusing on the 32Hz octave band

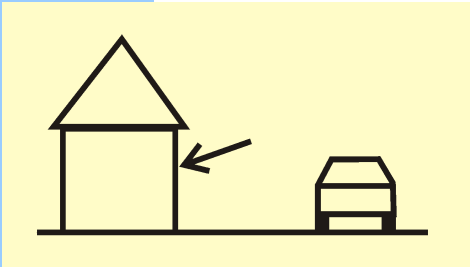
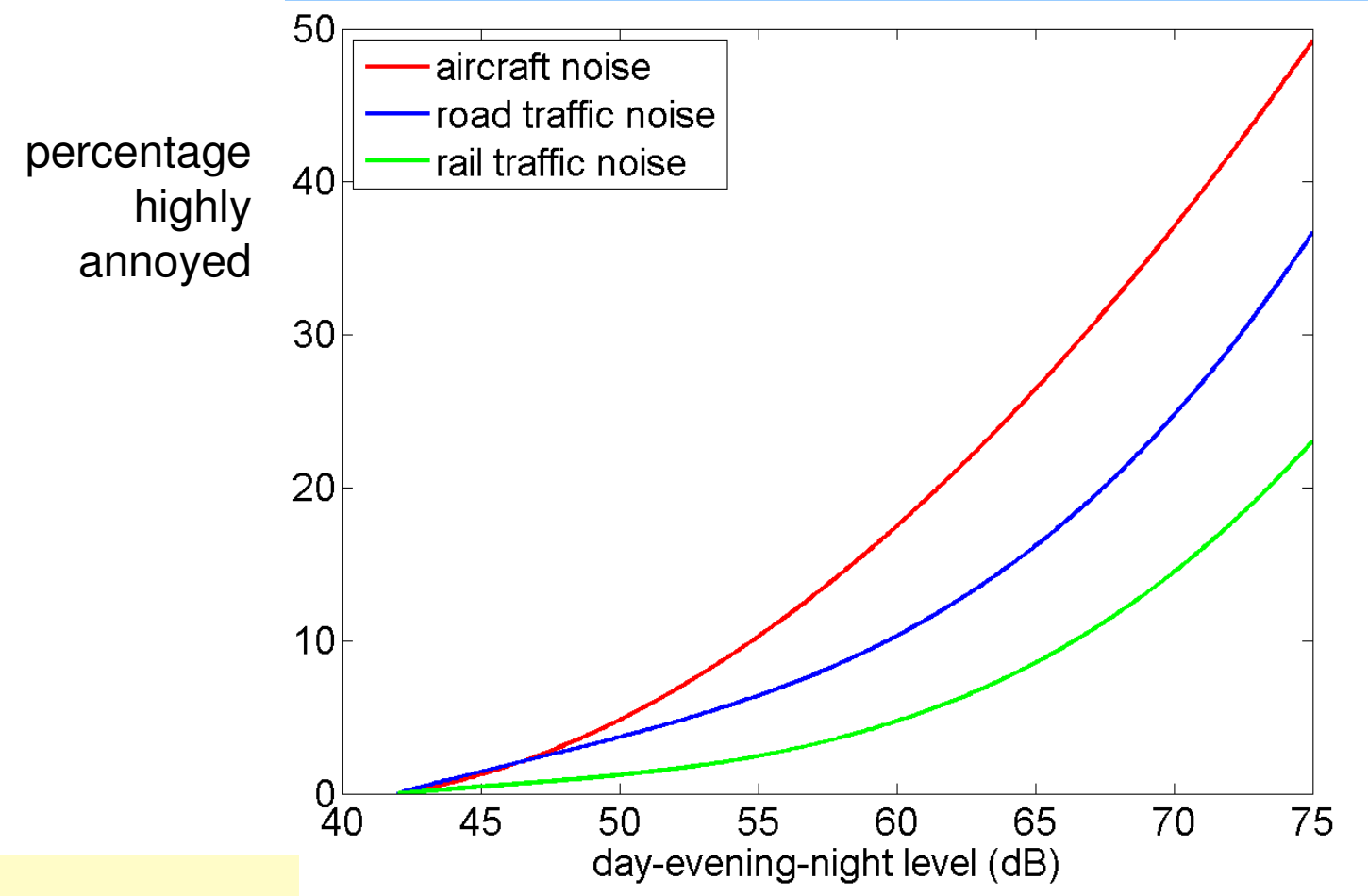
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# Outline

- Annoyance by environmental noise
  - traffic noise, aircraft noise, ...
- Low-frequency (LF) noise annoyance
  - national guidelines
  - laboratory studies
  - loudness at LF
  - spatial distribution in rooms
- Proposed method for rating LF noise

# Annoyance by environmental noise



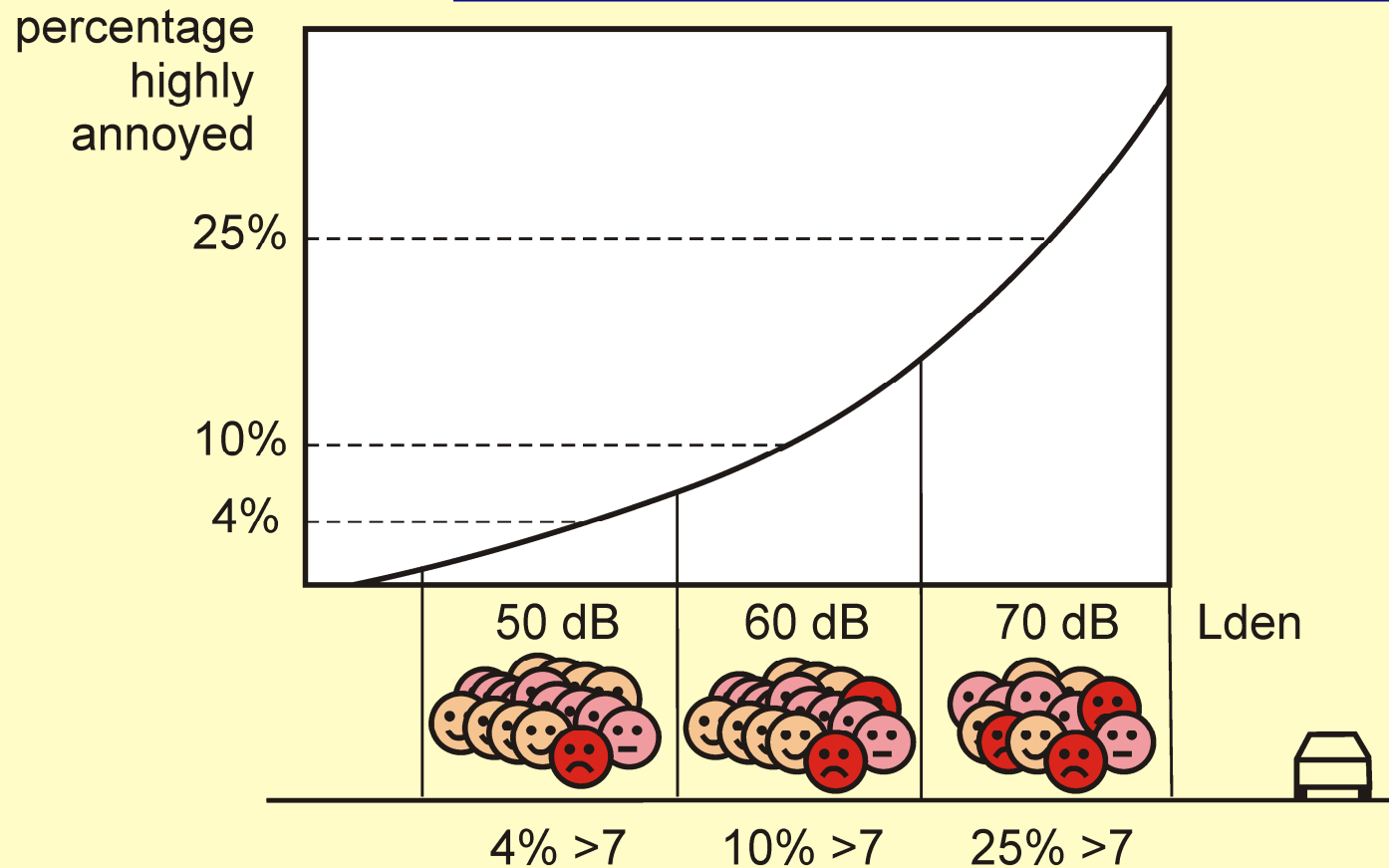
facade level



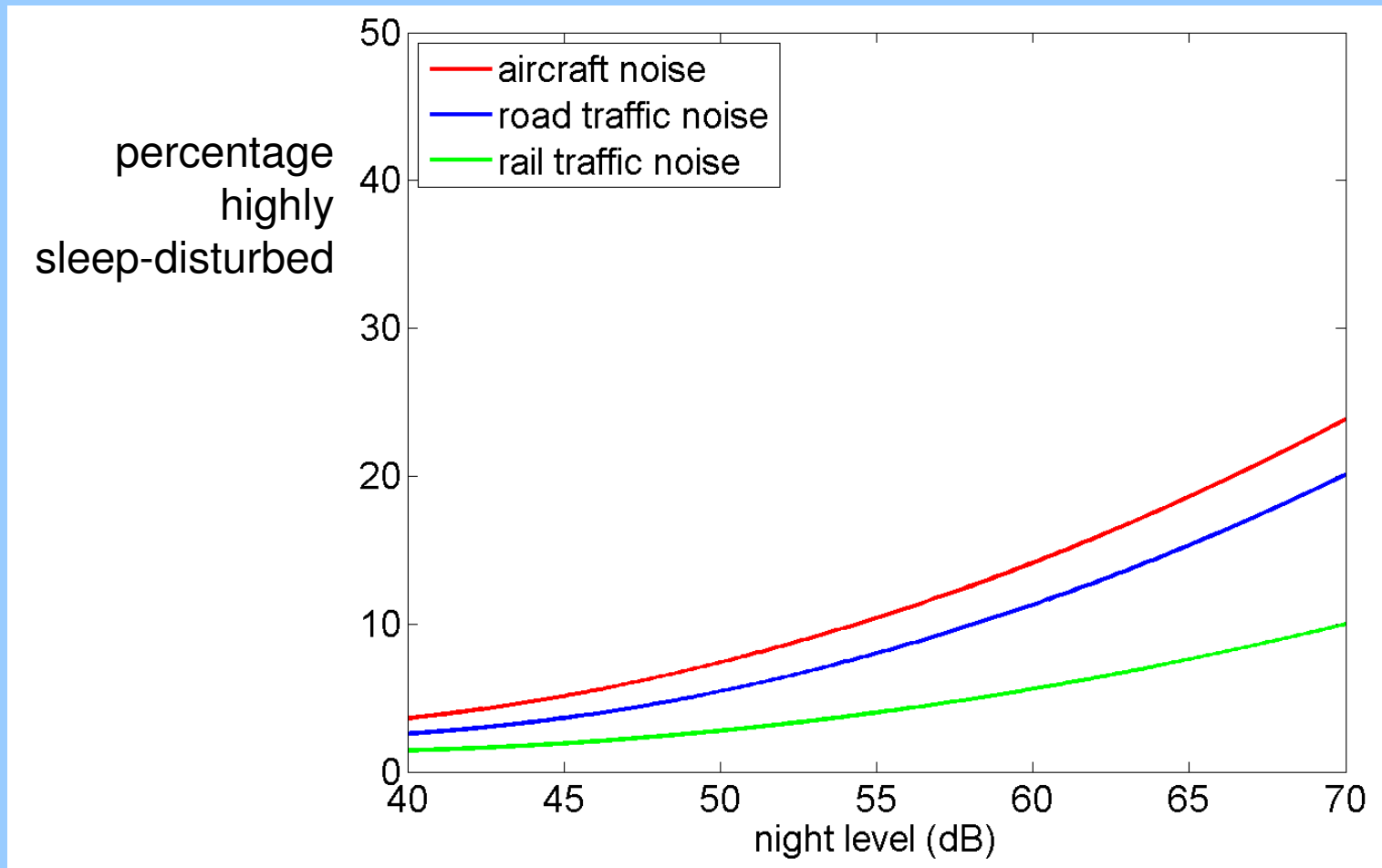
# Annoyance by environmental noise

How annoyed are you on a 0 – 10 scale?

highly annoyed: >7 on 0-10 scale



# Sleep disturbance by environmental noise



Night noise guidelines  
for Europe  
(WHO, 2009)

night level  
inside level

interim  
< 55 dB  
< 34 dB

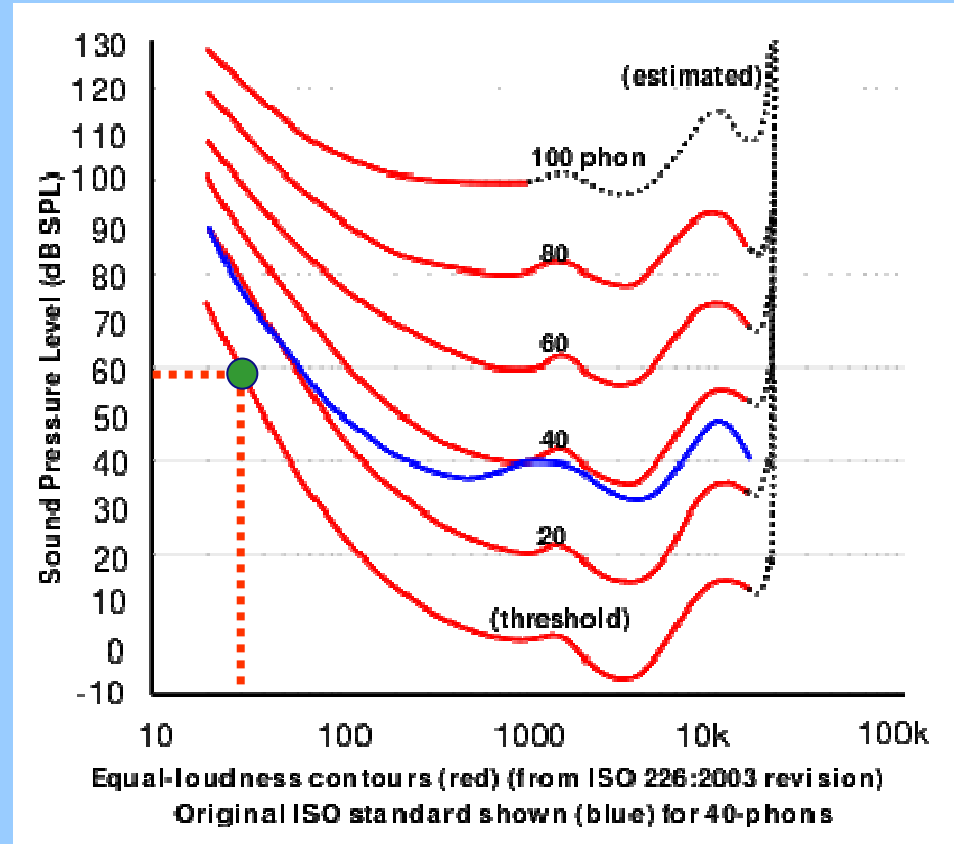
long term  
< 40 dB  
< 19 dB



# LF noise annoyance

National guidelines

hearing → possible annoyance



32 Hz

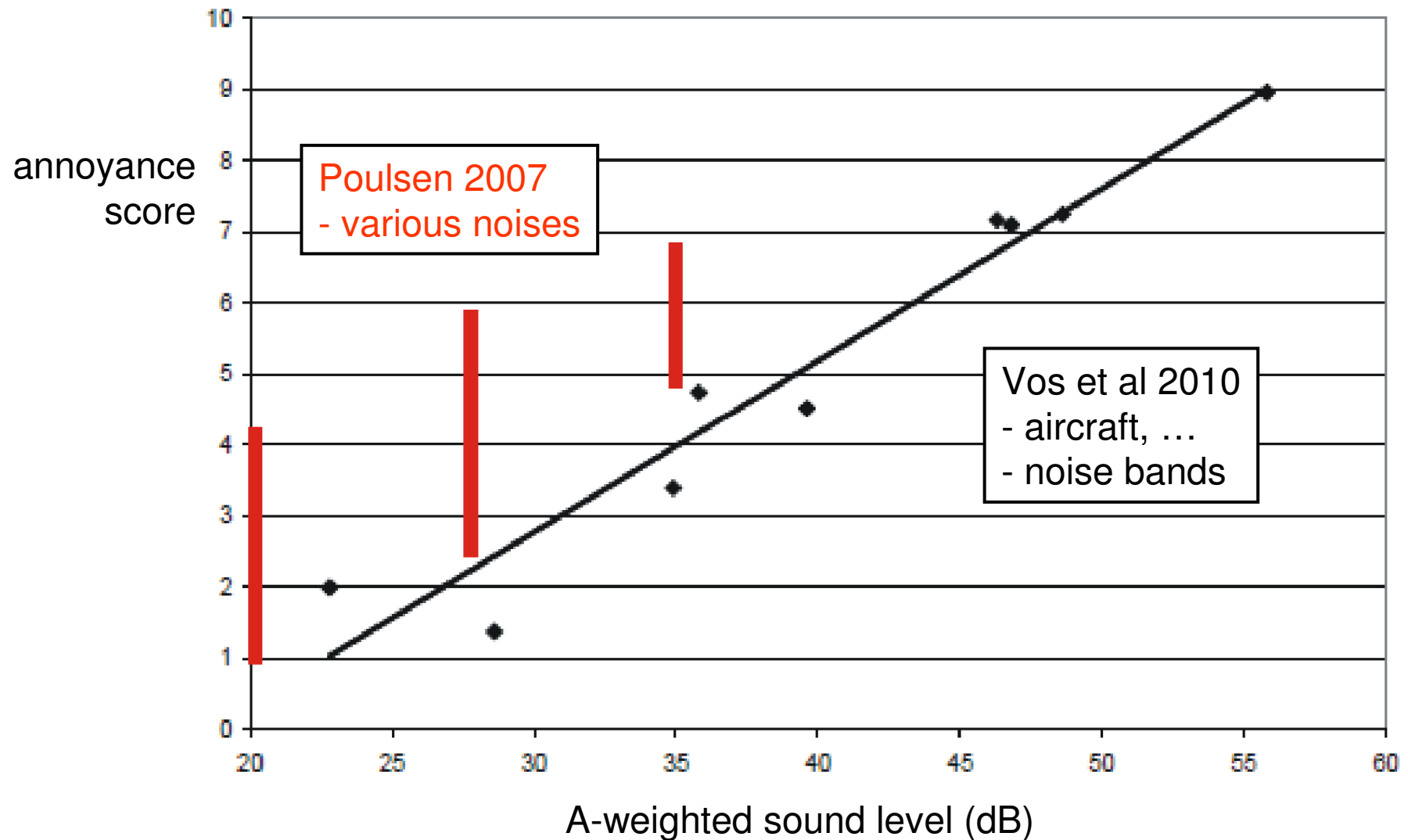
limit levels

hearing threshold

	PO	DE	NL	DK	SE	ISO 226 1987	ISO 226 2003
unweighted	49.3	55.5	55.0	59.4	56.0	56.3	59.5
A-weighted	9.9	16.1	15.6	20.0	16.6	16.9	20.1

# LF noise annoyance: laboratory experiments

How annoying, if heard for longer time at home?



# LF noise annoyance: laboratory experiments

## Conclusion

- Good predictor for annoyance  
A-weighted sound level at the ear
- Annoyance score  $< 3$  at 30 dB



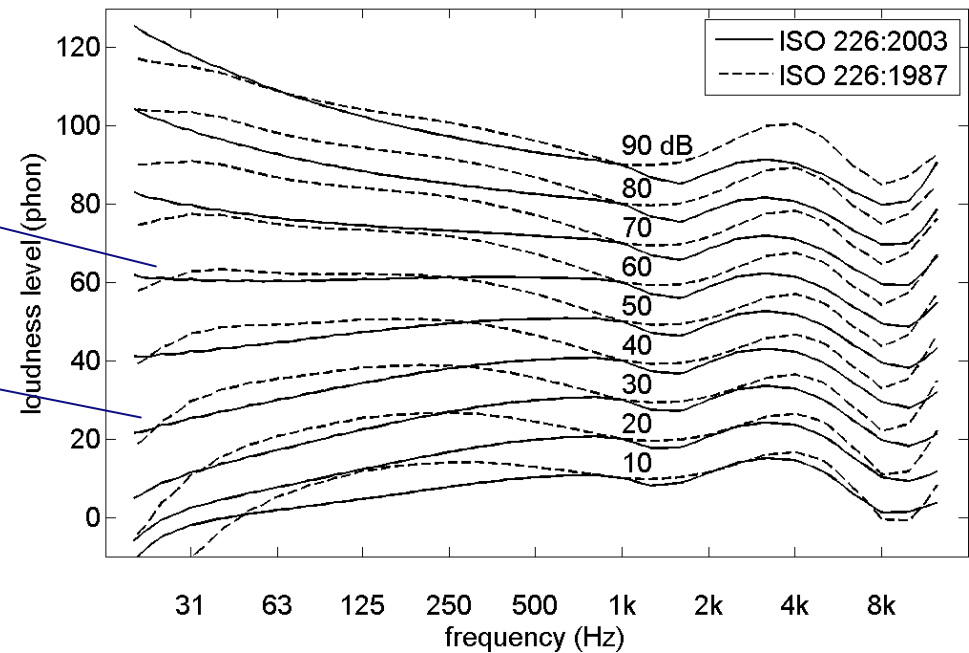
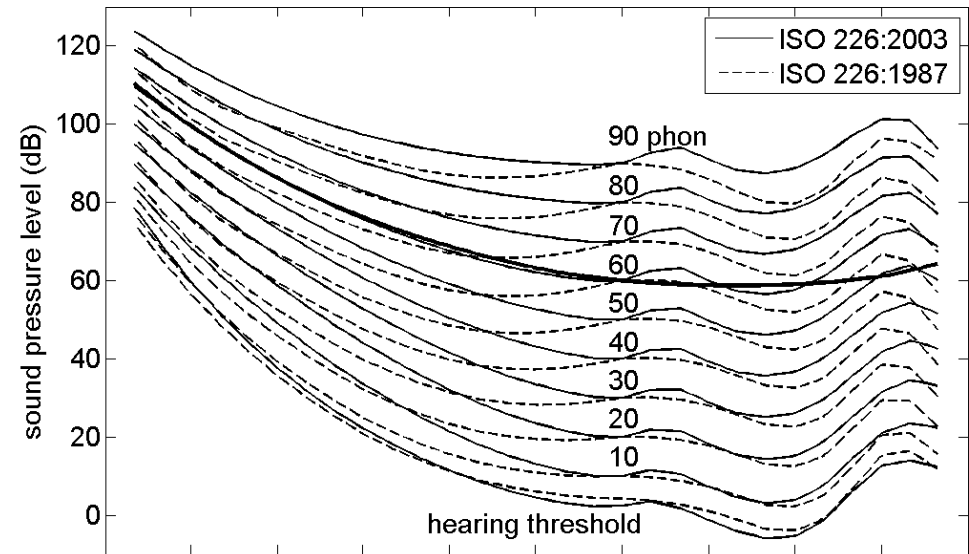
# LF noise and loudness

equal-loudness contours  
ISO 226

at 60 dB A-weighted sound level:  
loudness is constant

at lower level:  
loudness decreases with  
decreasing frequency

Conclusion  
no reason for LF noise penalty



# Spatial variations in rooms

room 6 x 5 x 3.4 m

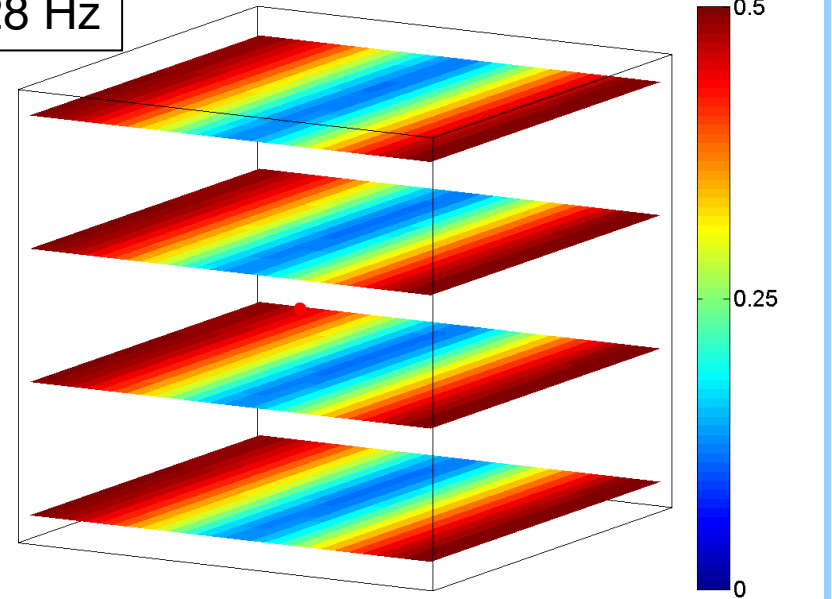
32 Hz wavelength 10 m →  
resonances in rooms

maximum levels in corners

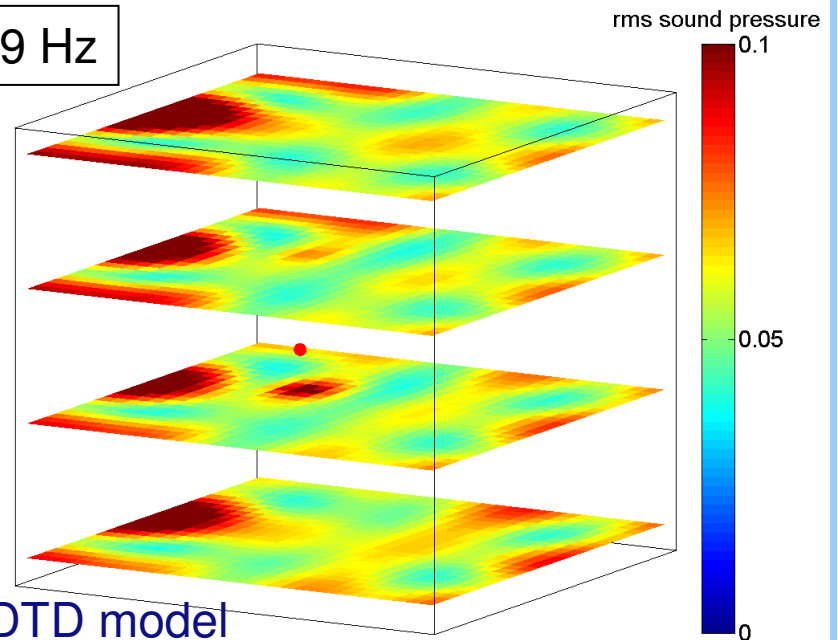
Pedersen, Moller, Persson Waye (2008)

- LF noise annoyance:  
maximum indoor levels
- Proposal: level L10
- Estimate: 3 random corners

28 Hz

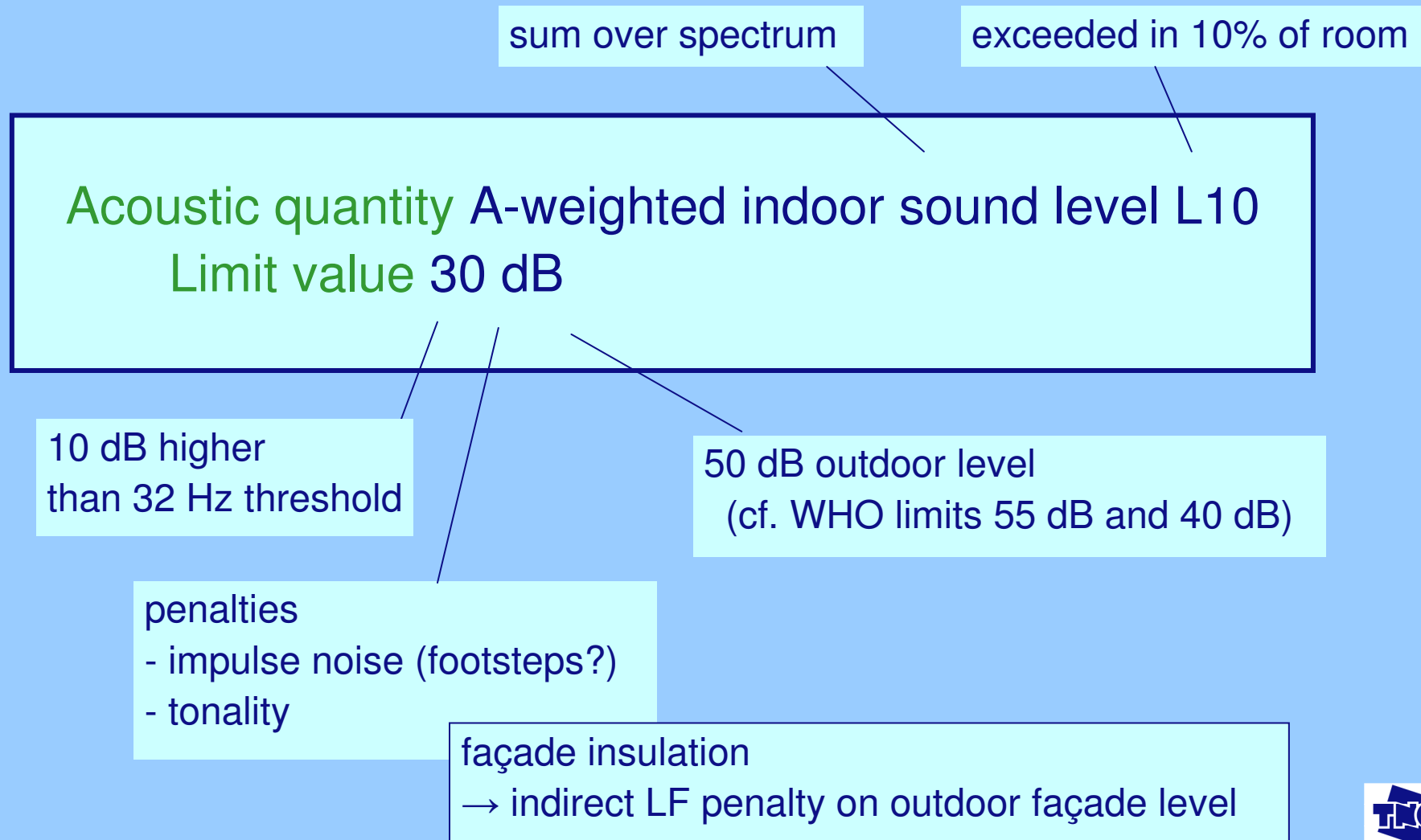


79 Hz



FDTD model

# Proposed method for rating LF noise



# Conclusions

- Current national guidelines LF noise
  - Based on hearing threshold
  - Too severe
- Method for LF noise annoyance
  - Predictor: A-weighted indoor level L10
  - Limit value 30 dB
- Facade insulation
  - indirect LF penalty on outdoor façade level