Aalto University
School of Electrical
Engineering

Communication acoustics
Ch 9: Basic function of hearing

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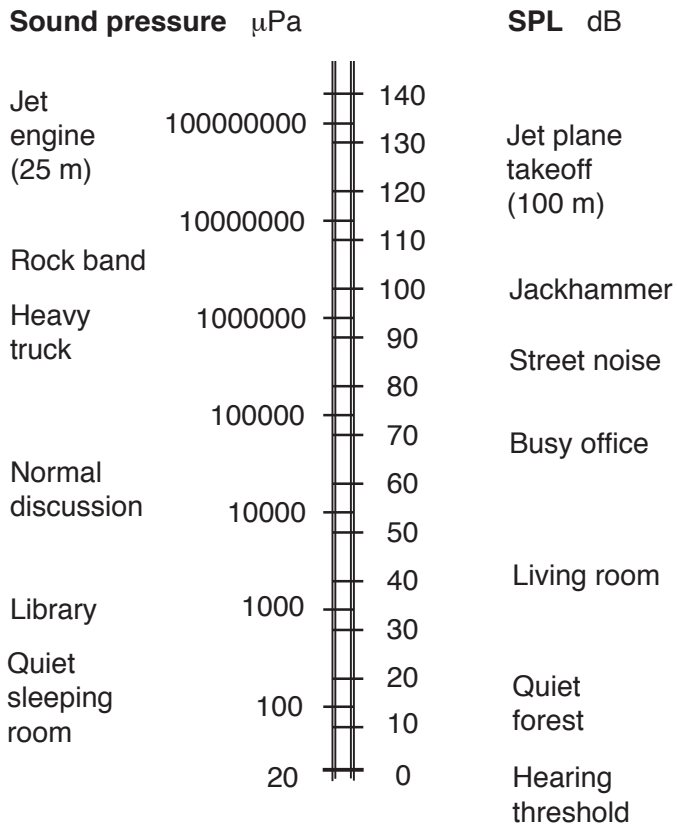
September 19, 2017

This chapter

- Effective hearing area
- Spectral masking
- Temporal masking
- Frequency selectivity of hearing

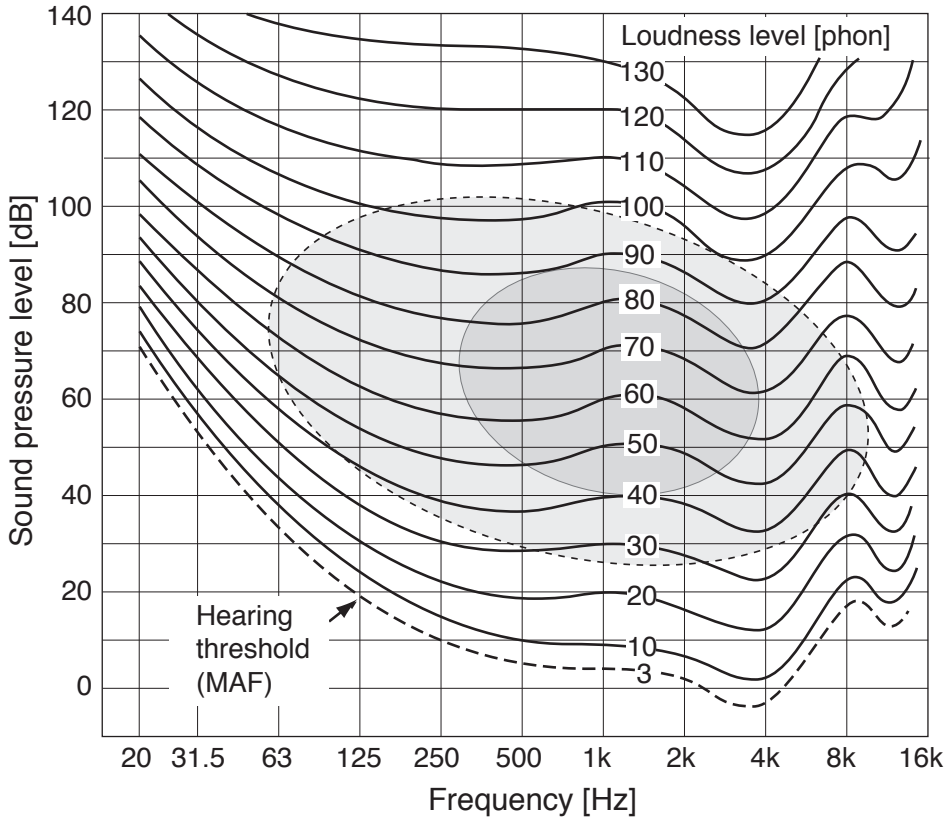
Effective hearing area

- Dynamic range of hearing



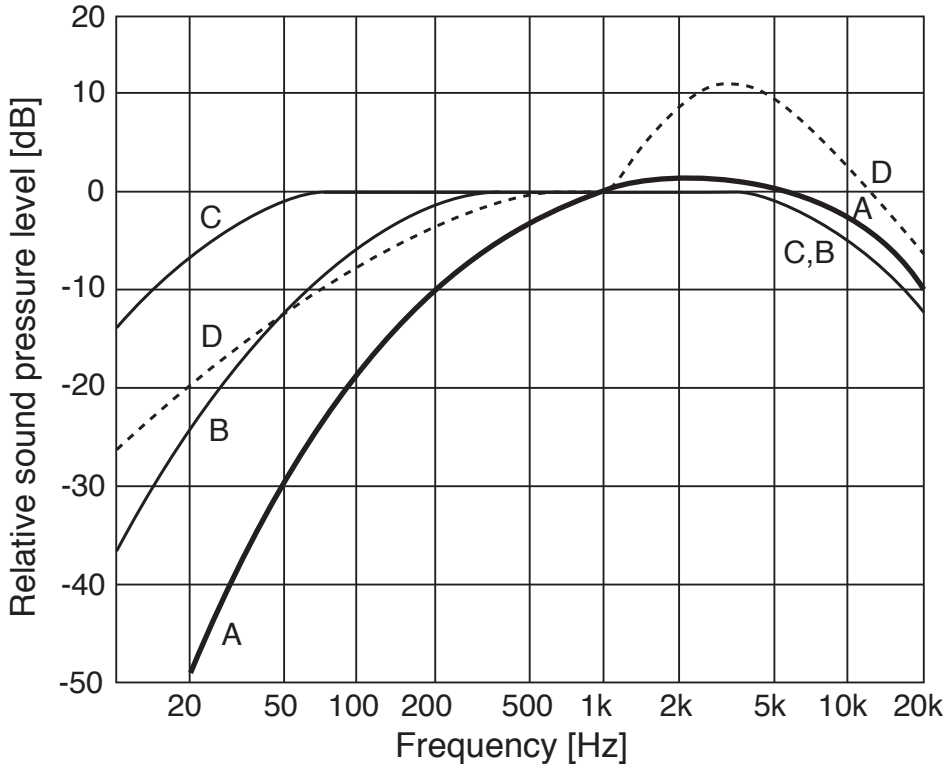
Effective hearing area

- Equal loudness contours
- Fletcher Munson curves



Sound level and frequency weighting curves

- Weighting filters for sound level measurement (A most common)
- Measured pressure level should match the loudness perceived by the listener

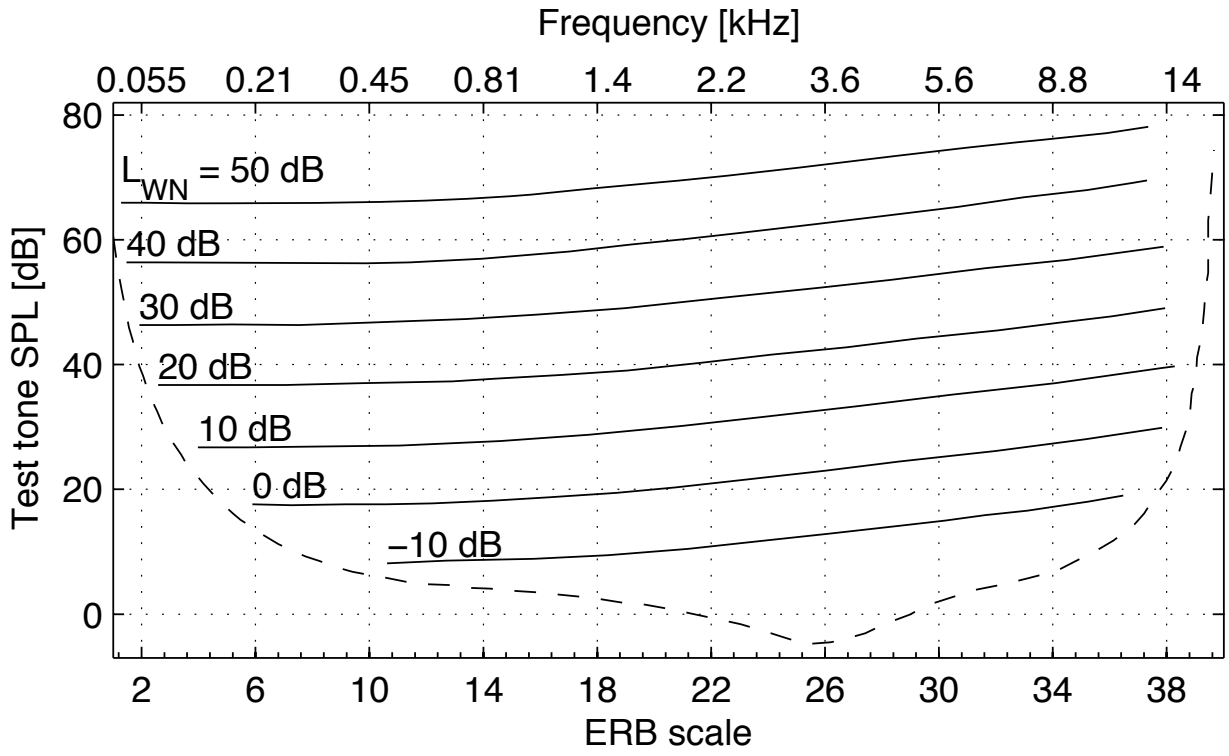


Masking effect

- A loud sound makes a weaker sound imperceptible
- Categories and aspects of masking
  - Frequency masking
  - Temporal masking
  - Time-frequency masking
  - Frequency selectivity of the auditory system
  - Psychophysical tuning curves
  - Critical band
- Bark bandwidth
- ERB bandwidth

Frequency masking

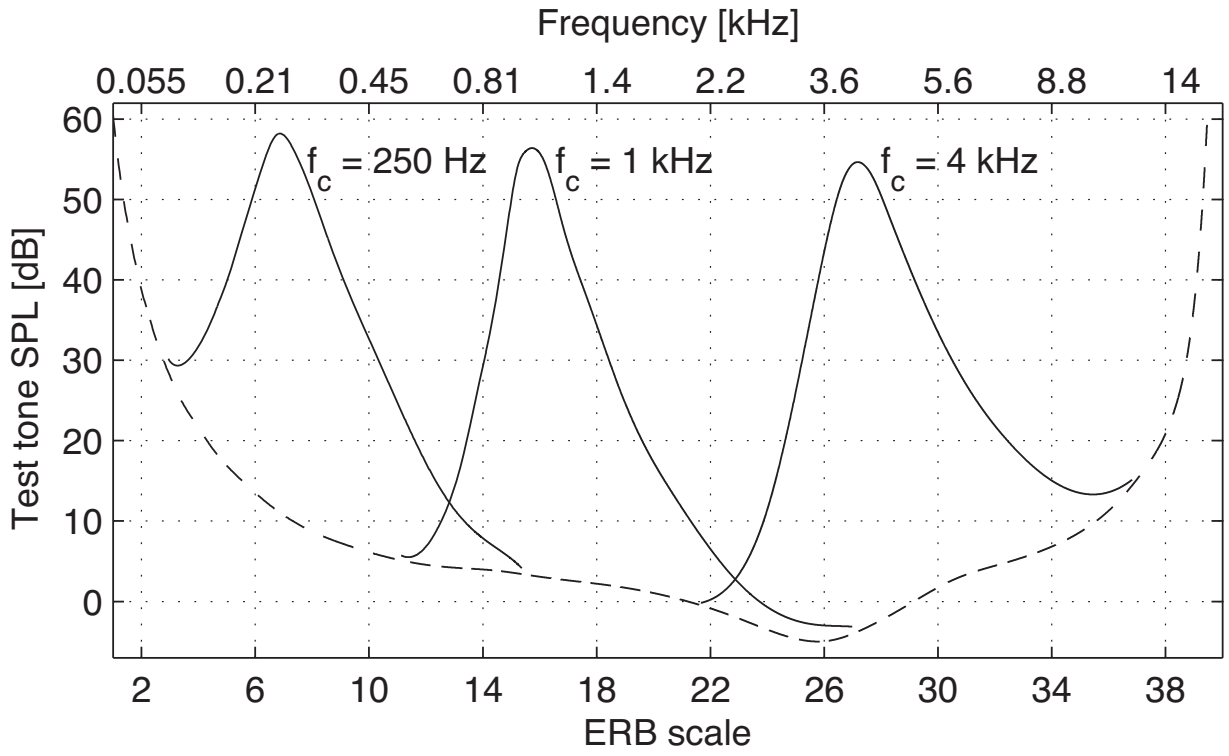
- Masking by white noise



Adapted from Fastl and Zwicker (2007)

Frequency masking

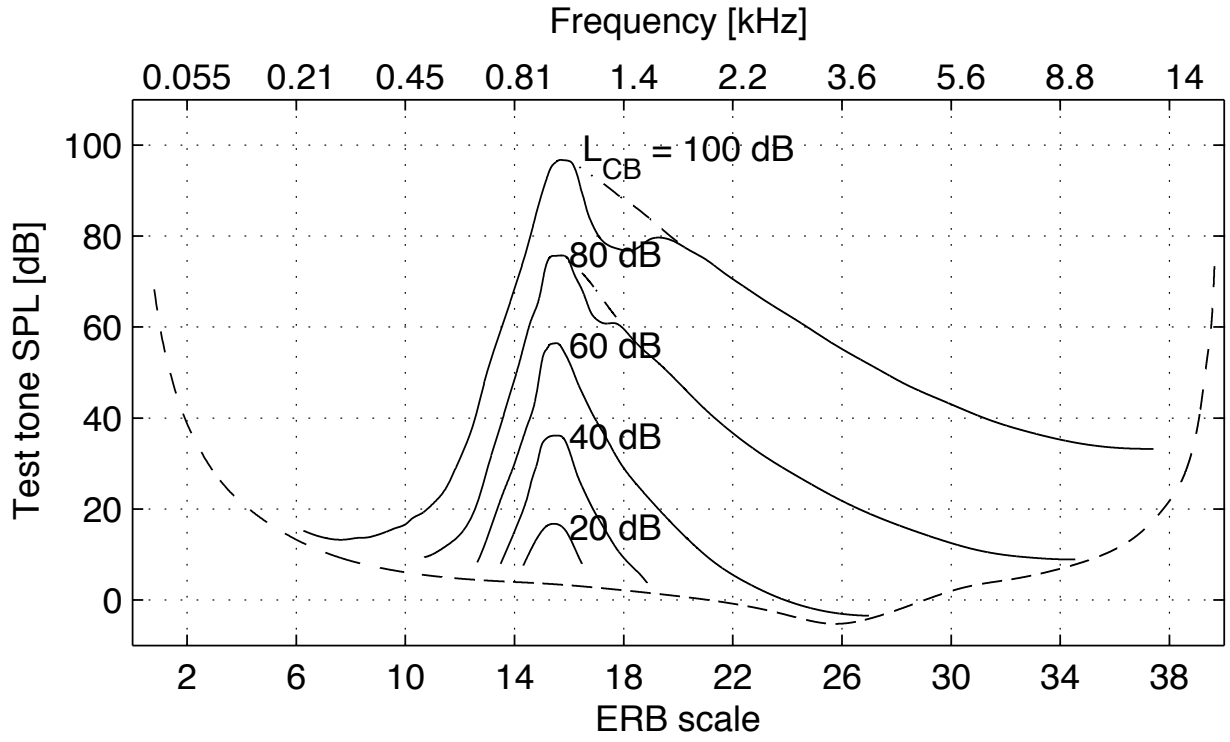
- Masking by narrow-band noise



Adapted from Fastl and Zwicker (2007)

Frequency masking

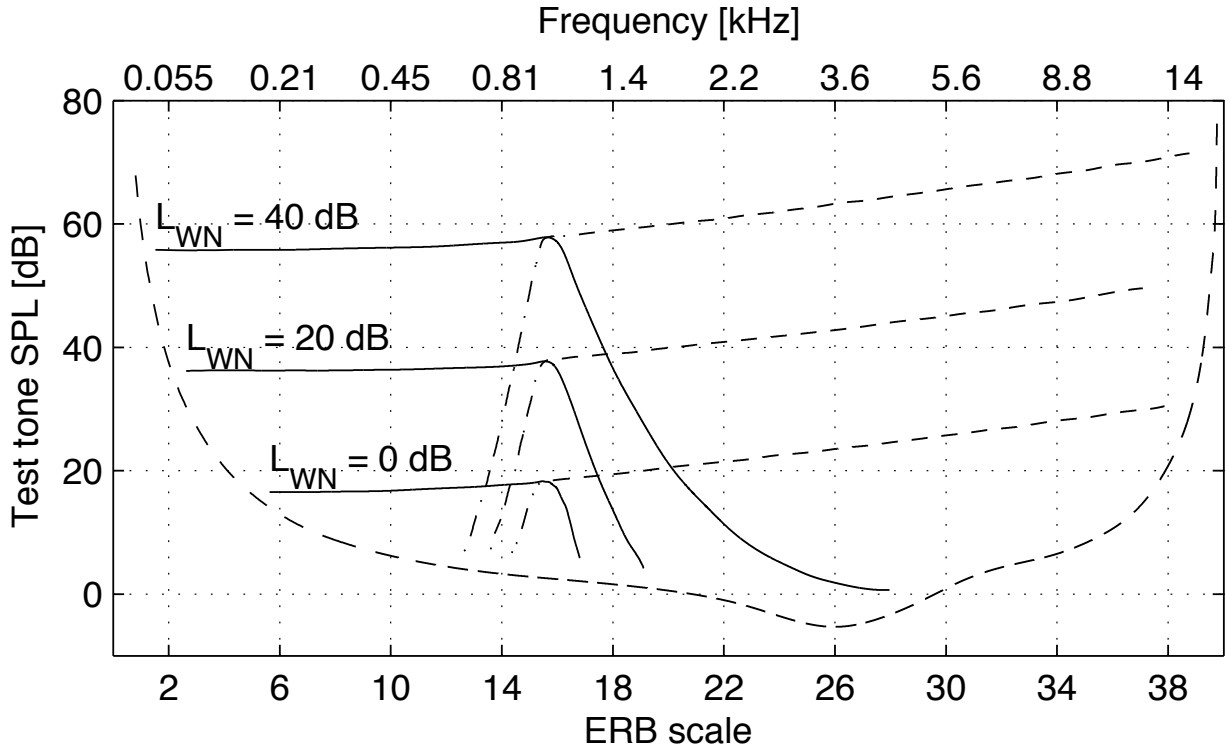
- Masking as function of the level of masker



Adapted from Fastl and Zwicker (2007)

Frequency masking

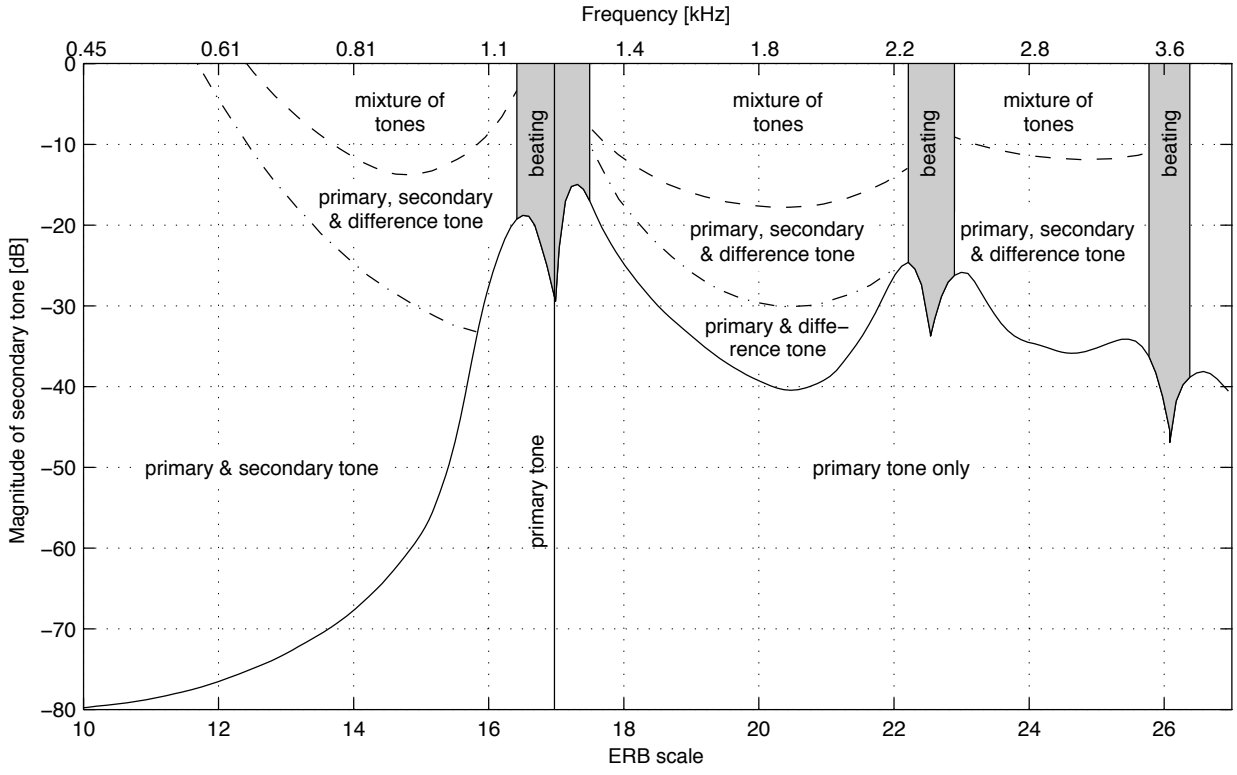
- Frequency masking by lowpass and highpass noise



Adapted from Fastl and Zwicker (2007)

Frequency masking

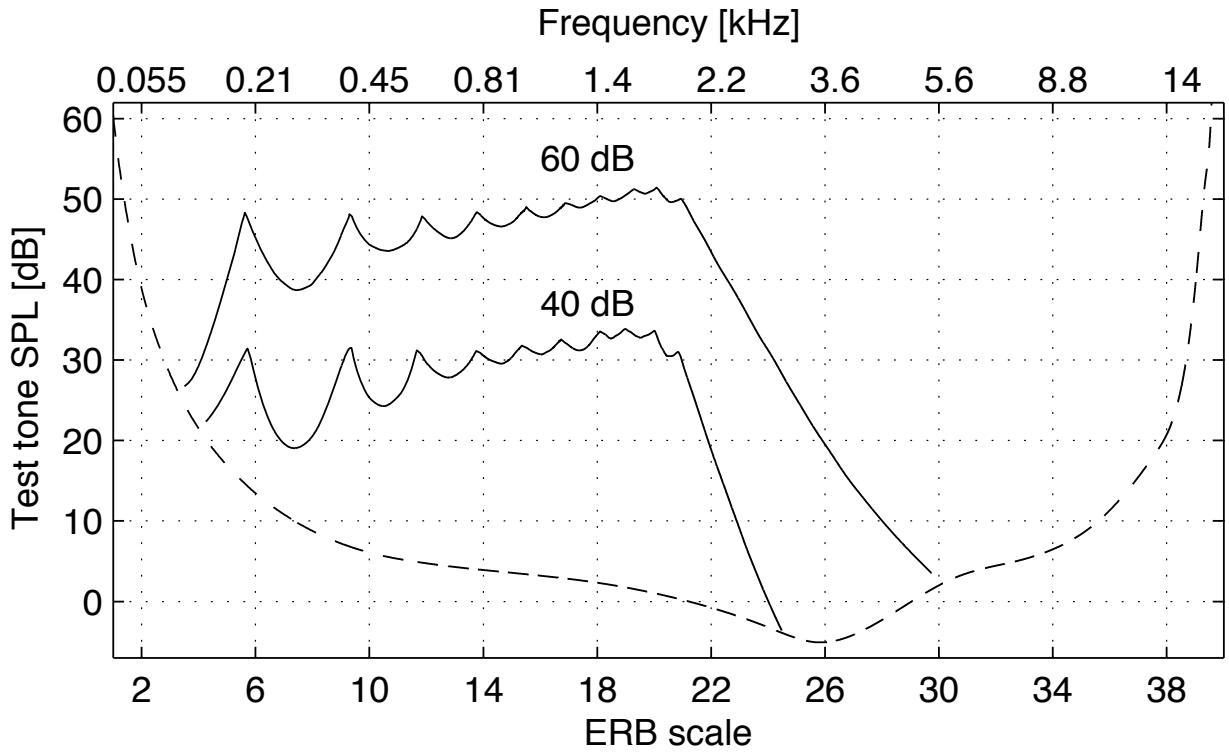
- Frequency masking by 1kHz tone



Adapted from Wegel and Lane (1924)

Frequency masking

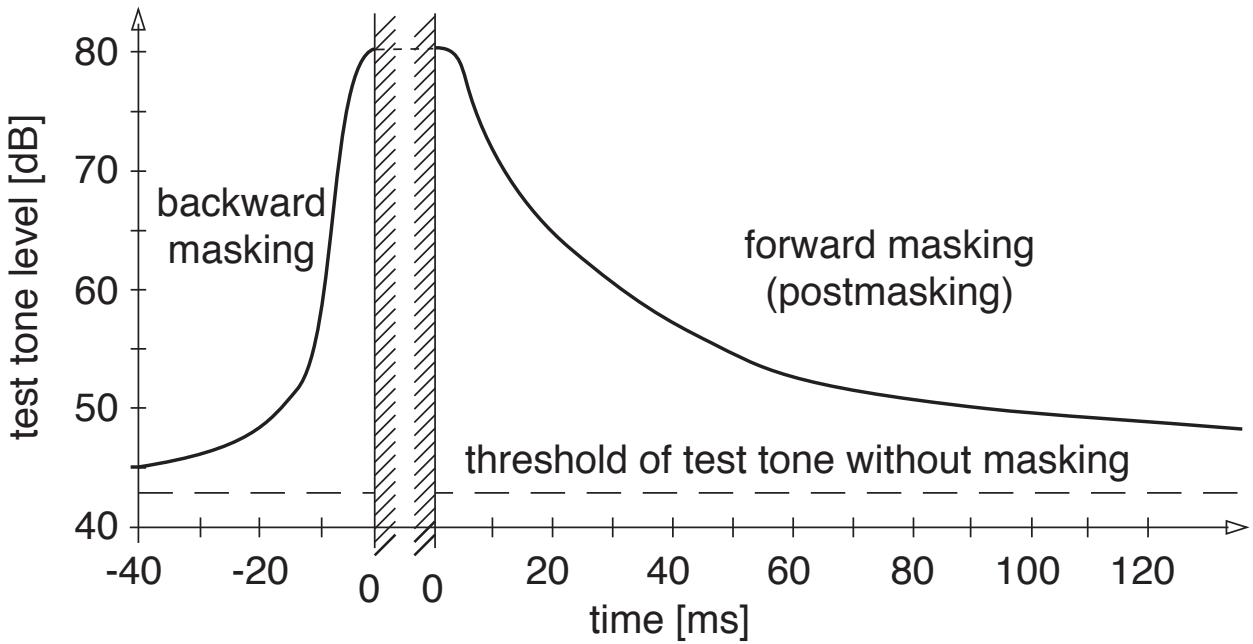
- Frequency masking by harmonic tone complex



Adapted from Fastl and Zwicker (2007)

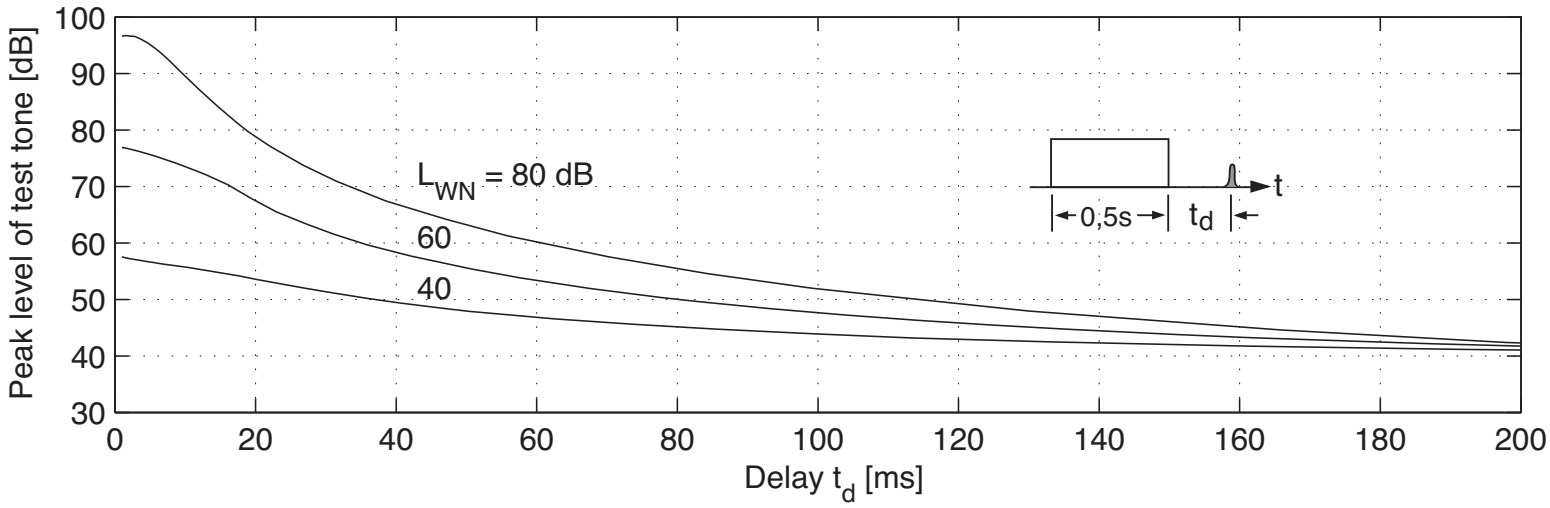
Temporal masking

- Masking before and after a noise signal
- Forward masking (noise masks sounds forward in time) / backward masking



Temporal masking

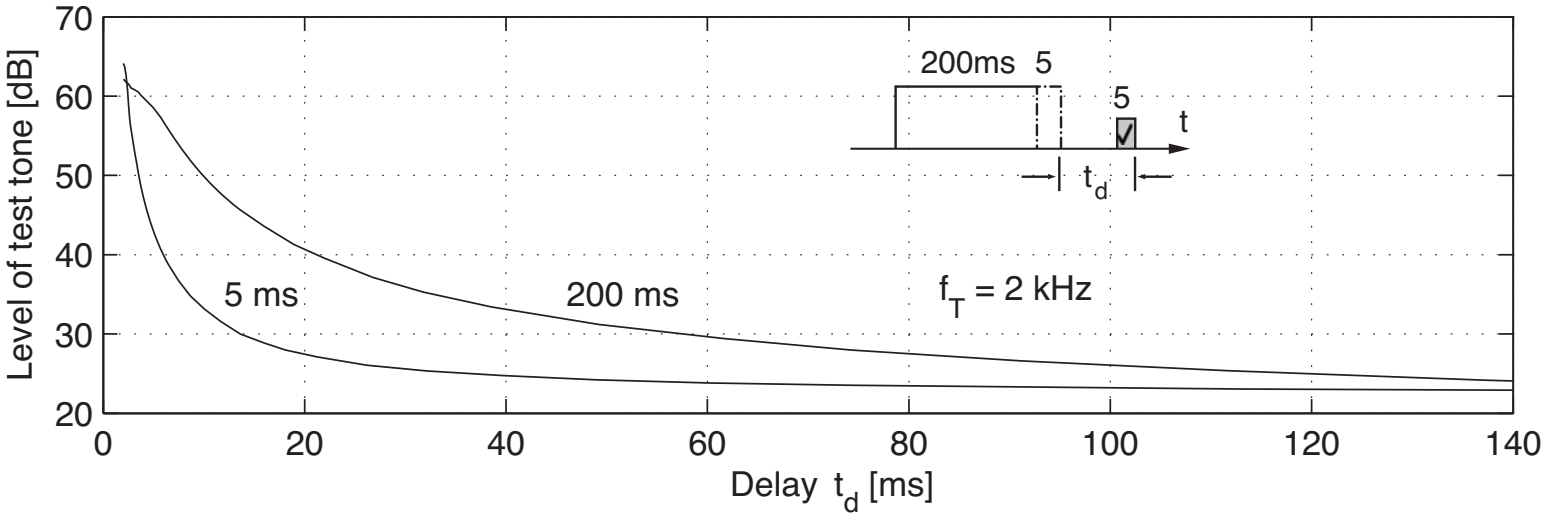
- Forward masking with different masking levels



Adapted from Fastl and Zwicker (2007)

Temporal masking

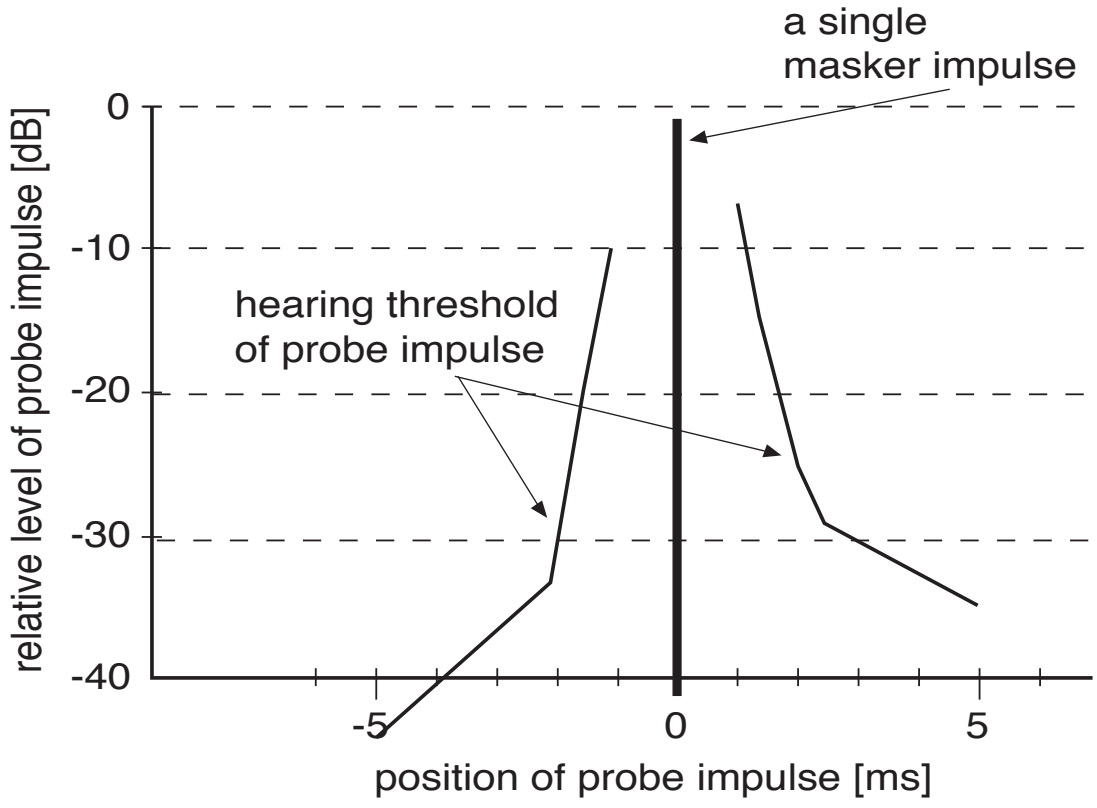
- Forward masking with different lengths of masking noise



Adapted from Fastl and Zwicker (2007)

Temporal masking

- Masking by an impulse



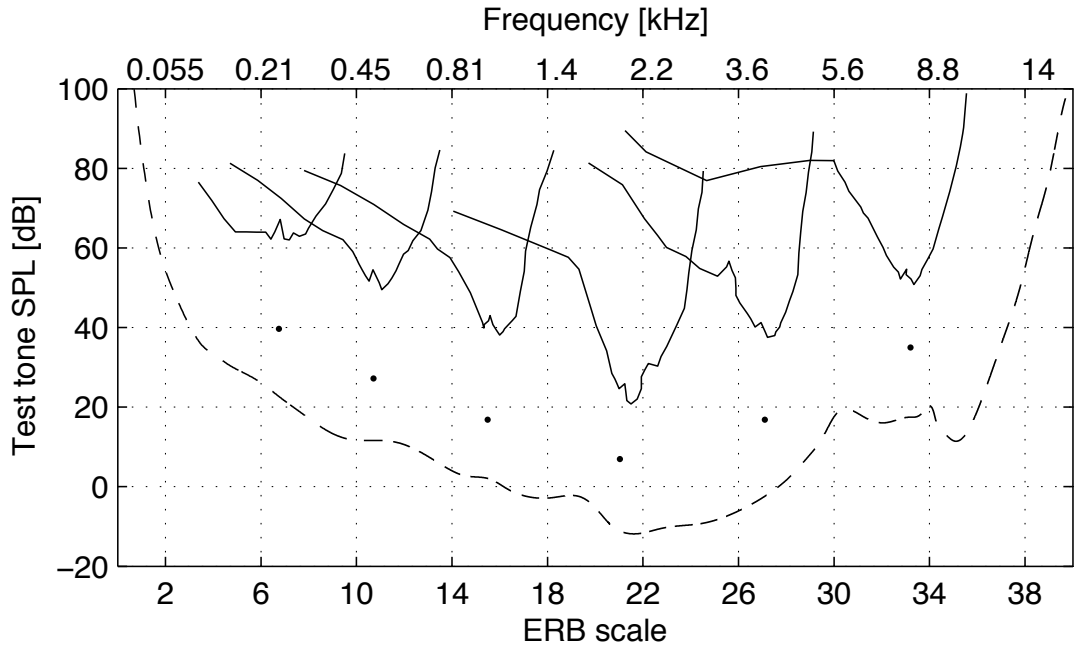
Adapted from Feth and O'Malley (1977)

Frequency selectivity of hearing

- When sinusoids are far from each other in frequency, they are perceived as two static sinusoids
- When the frequencies are enough near, sinusoids interact
- Frequency masking has strongest effect to nearby frequencies
- Humans have a certain frequency selectivity
- All frequency components inside "critical band" are merged together, not accessible separately

Frequency selectivity of hearing

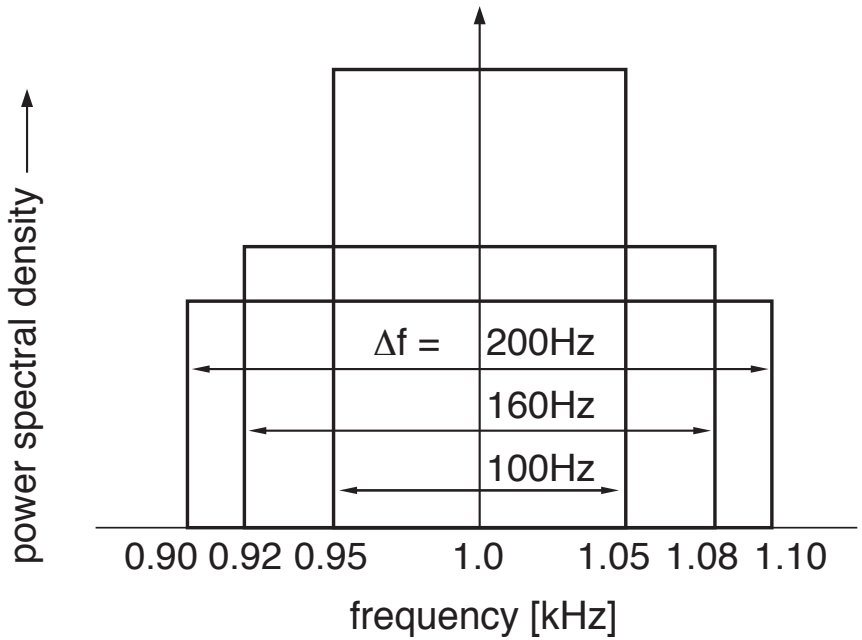
- Psychophysical tuning curves
- Masking threshold - low-level sinusoid as signal and narrowband noise as masker



Adapted from Vogten (1974)

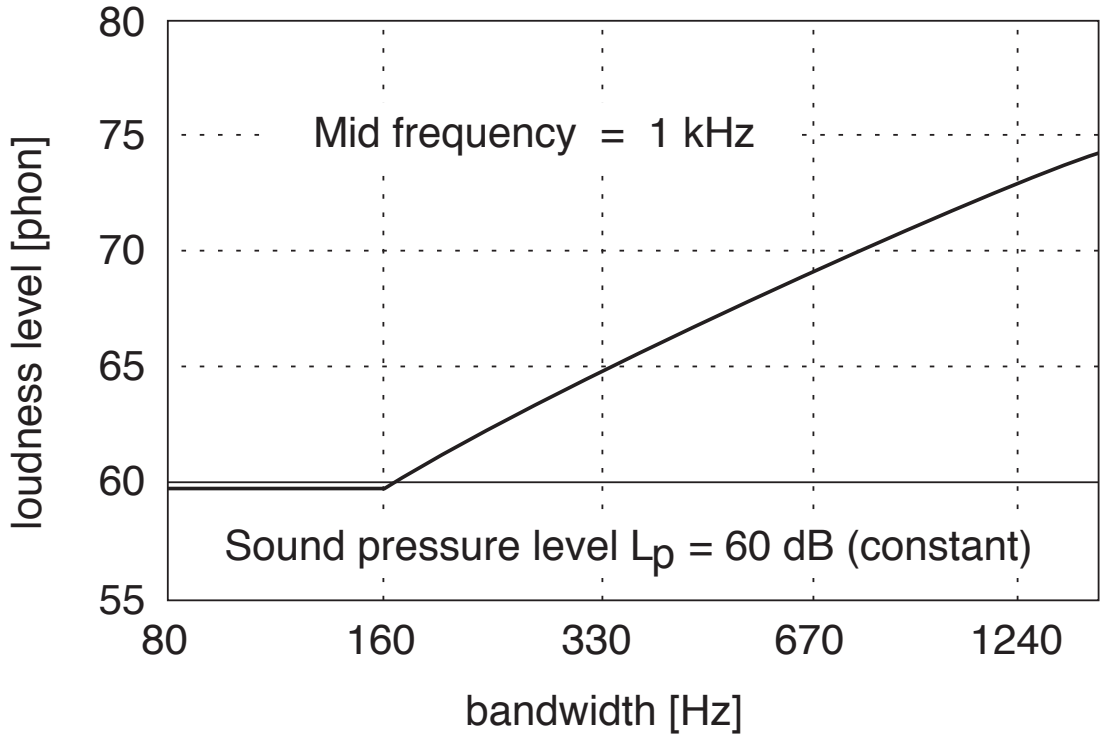
Measuring the width of critical bands

- Experiment: loudness vs. bandwidth of noise



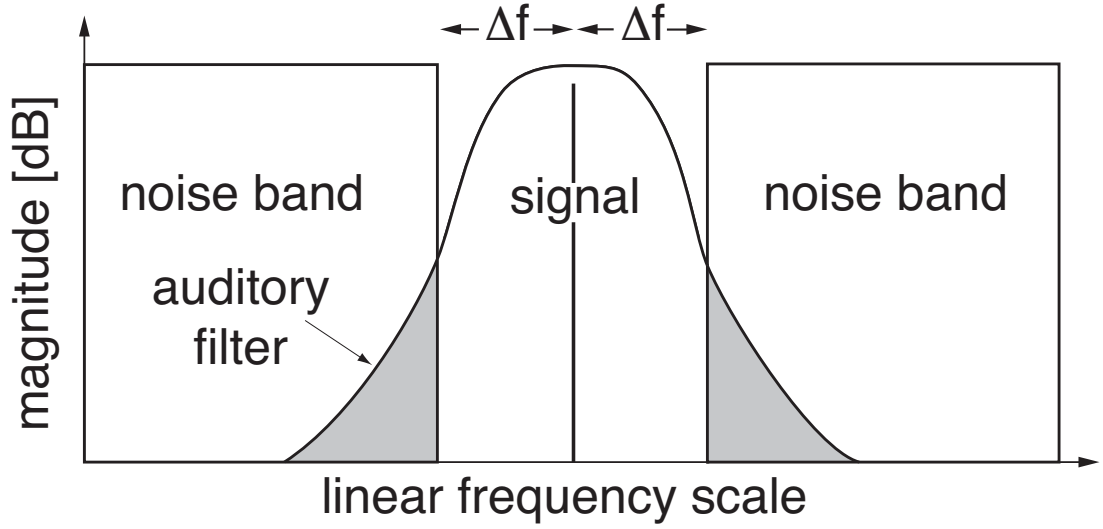
Measuring the width of critical bands

- Loudness increases when the banwidth increases the critical bandwidth



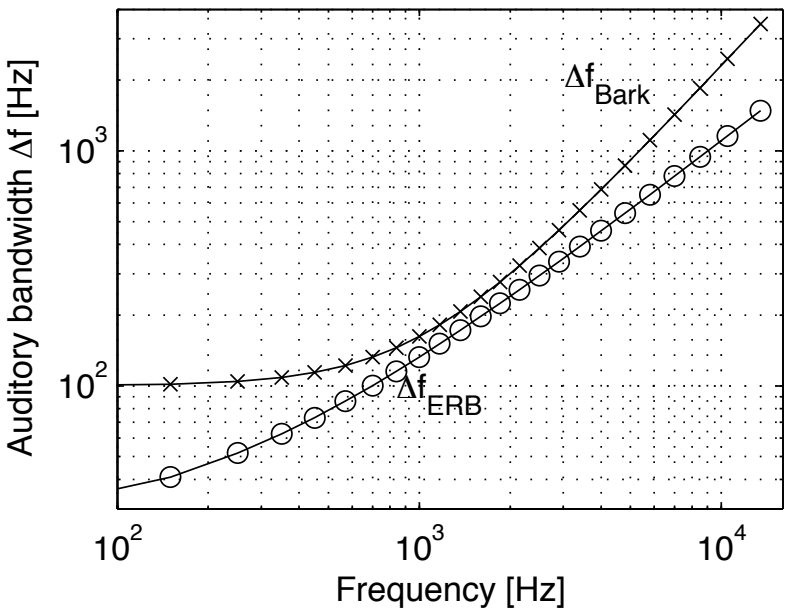
Measuring the width of critical bands

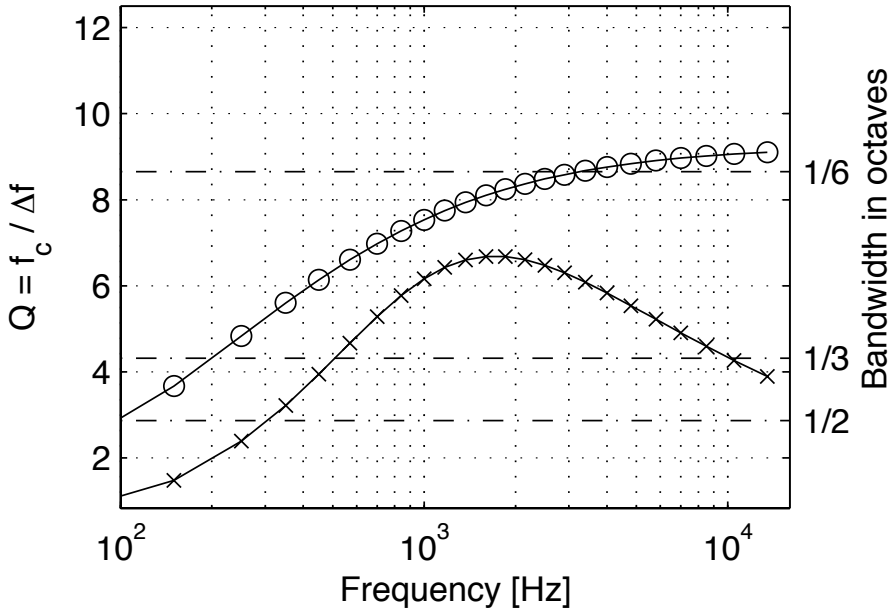
- Masking threshold of the signal is measured as function of the width of passband
- Equivalent rectangular bandwidth scale (ERB scale)



Width of critical bands

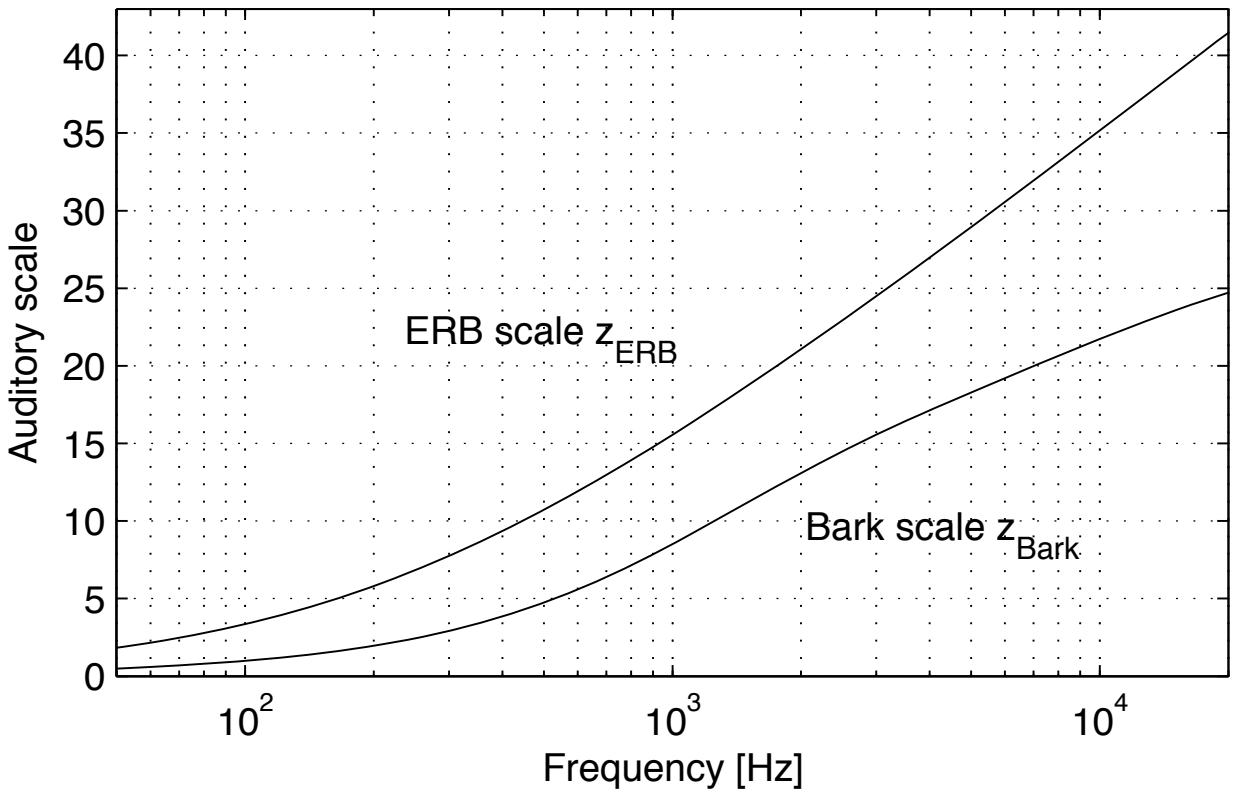
- Bark and ERB dependence on frequency





Auditory frequency scales

- Stack ERB and Bark bandwidths starting from a low frequency



References

These slides follow corresponding chapter in: Pulkki, V. and Karjalainen, M. Communication Acoustics: An Introduction to Speech, Audio and Psychoacoustics. John Wiley & Sons, 2015, *where also a more complete list of references can be found.*

References used in figures:

Fastl, H. and Zwicker, E. (2007) Psychoacoustics – Facts and Models. Springer.

Feth, L.L. and O'Malley, H. (1977) Influence of temporal masking on click-pair discriminability. Percep. Psychophys., 22(5), 497–505.

Vogten, L. (1974) Pure-tone masking: A new result from a new method Facts and Models In Hearing, Springer. pp. 142–155.

Wegel, R. and Lane, C. (1924) The auditory masking of one pure tone by another and its probable relation to the dynamics of the inner ear. Phys. Rev. 23(2), 266–285.