Aalto University
School of Electrical
Engineering

# Communication acoustics
# Ch 9: Basic function of hearing

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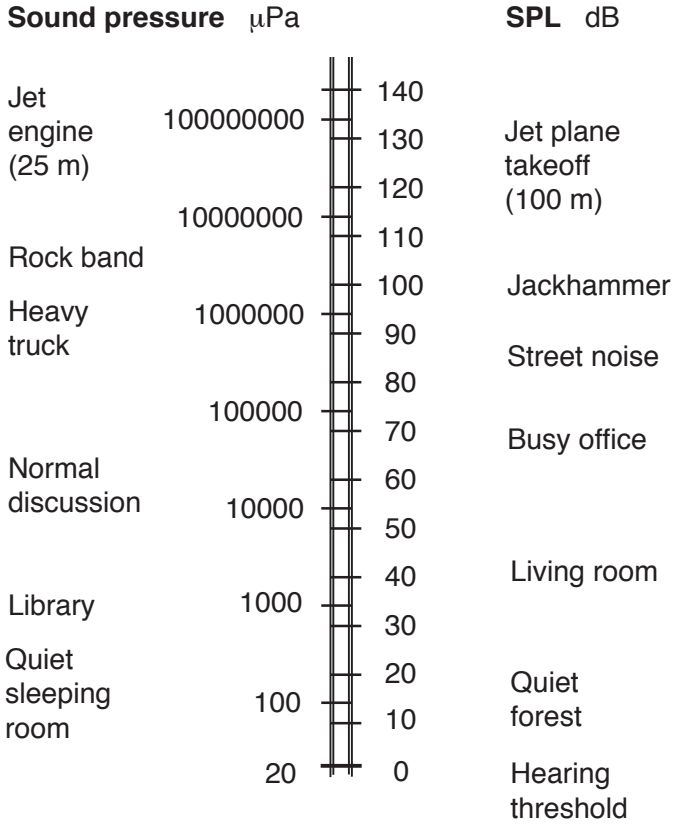
# This chapter

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

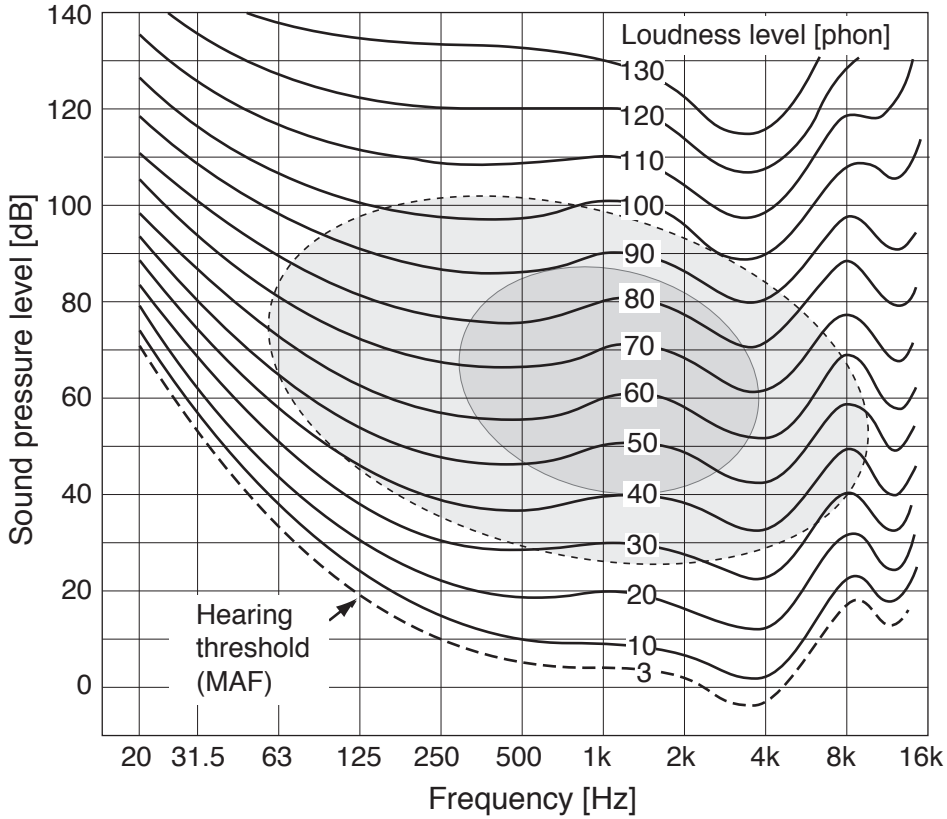
# Effective hearing area

- Dynamic range of hearing



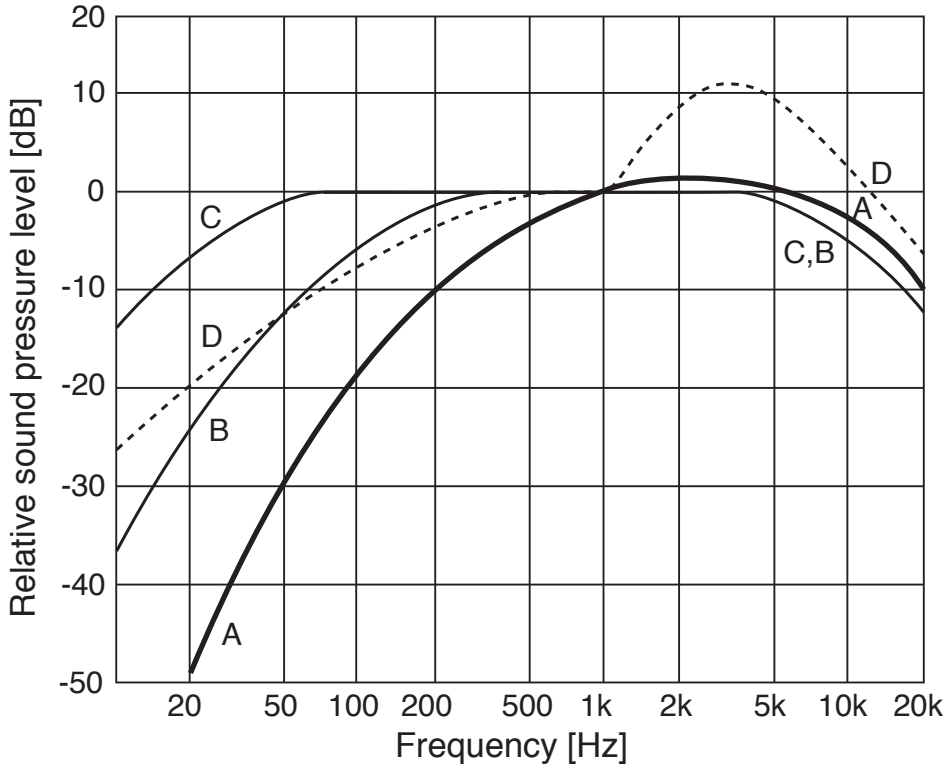
# Effective hearing area

- 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

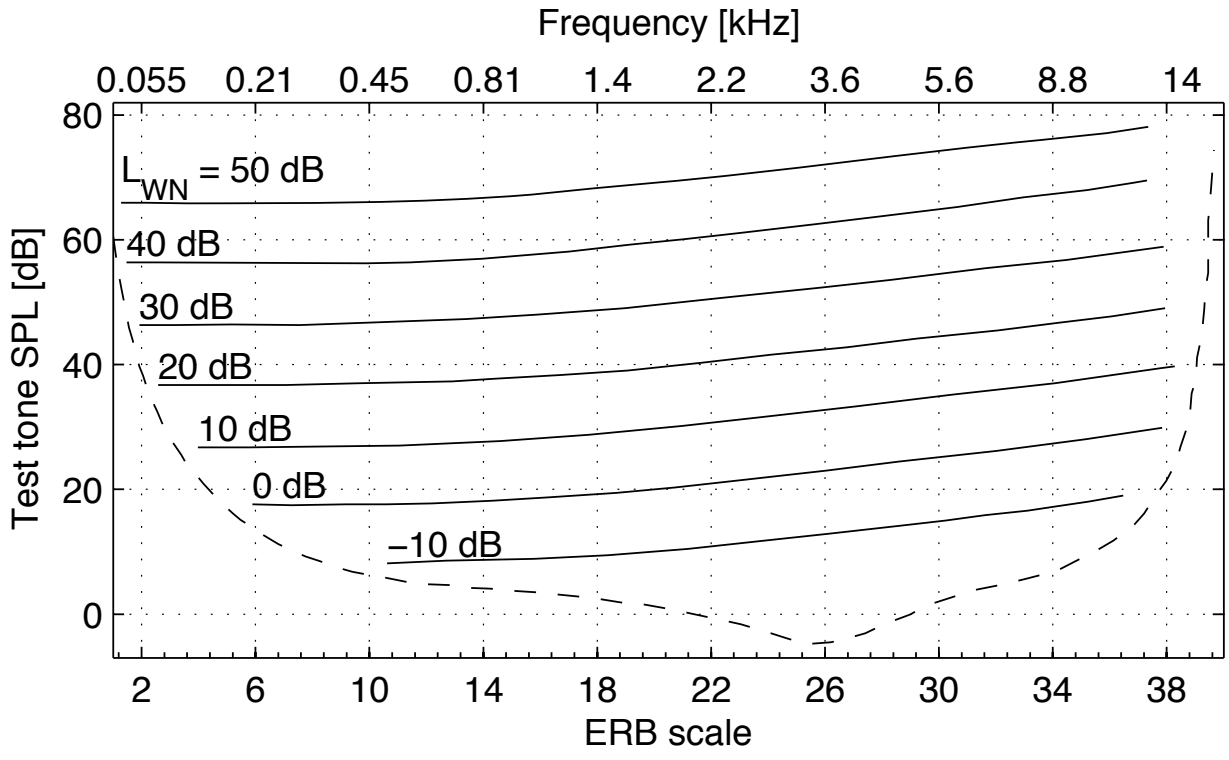


# Masking effect

- A loud sound makes a weaker sound imperceptible
- Categories 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

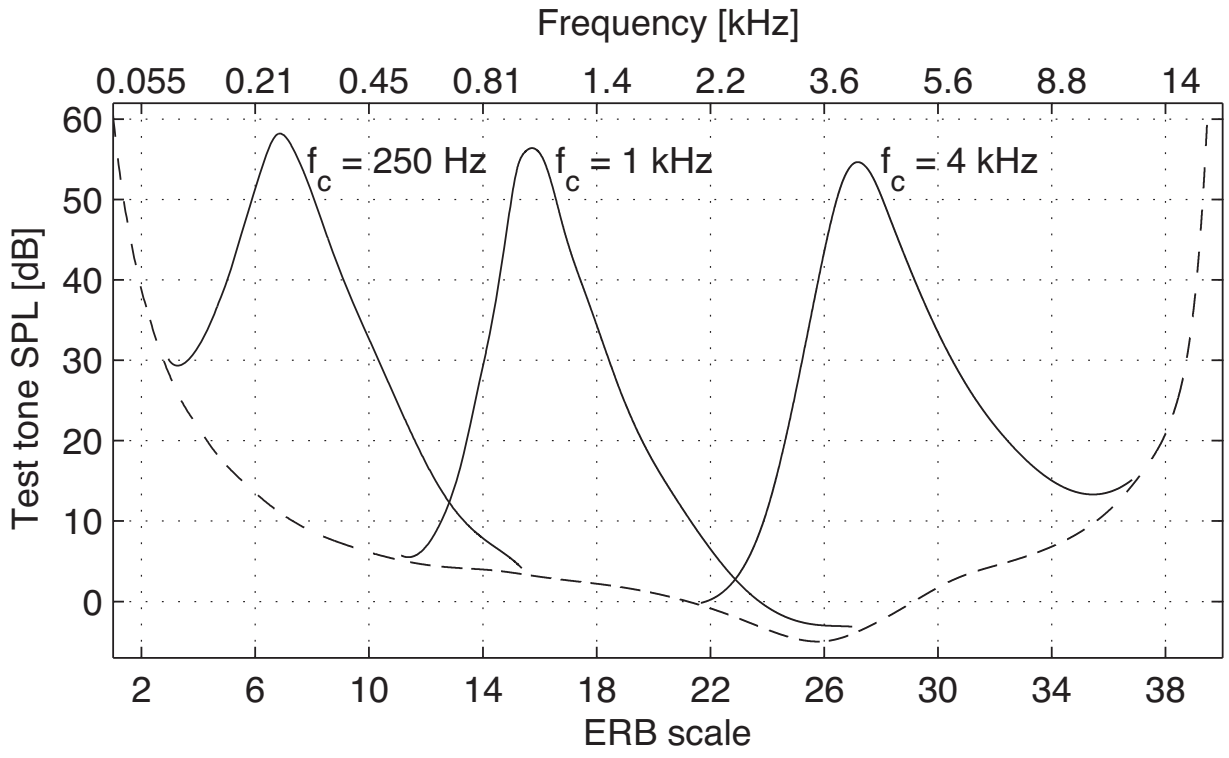
- Masking by white noise




Adapted from Fastl and Zwicker (2007)

# Frequency masking

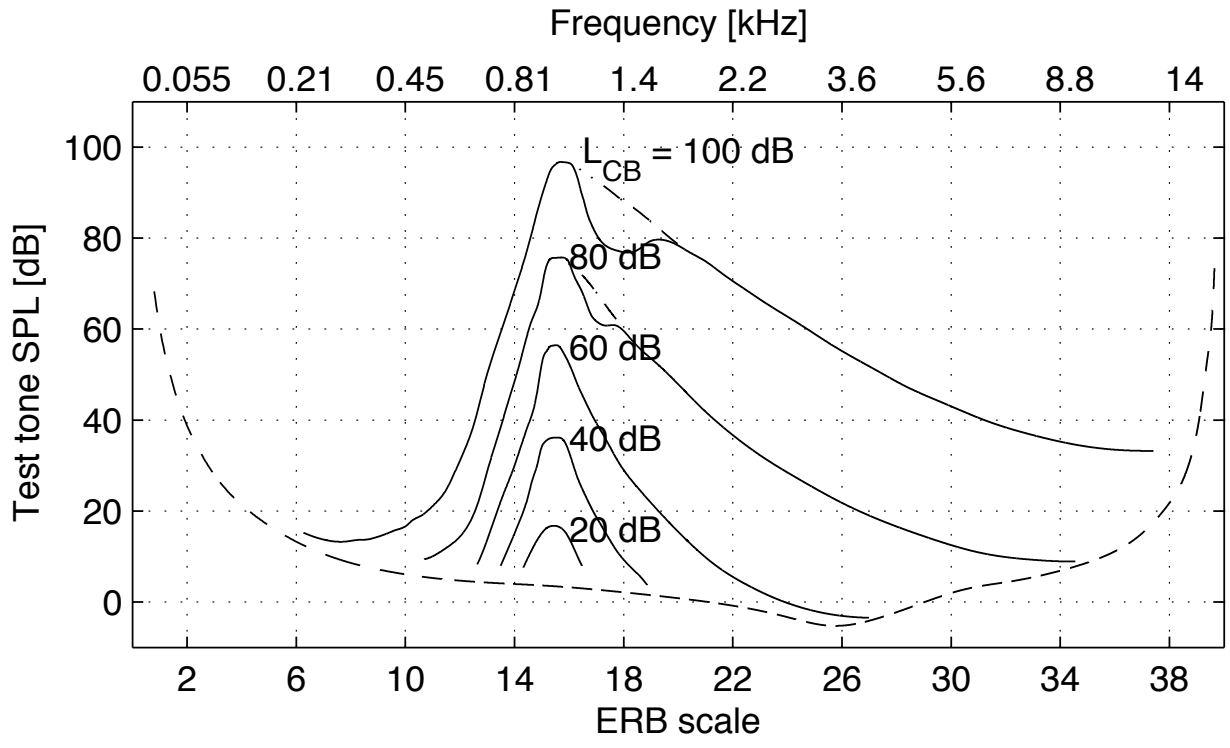
- Masking by narrow-band noise




Adapted from Fastl and Zwicker (2007)

# Frequency masking

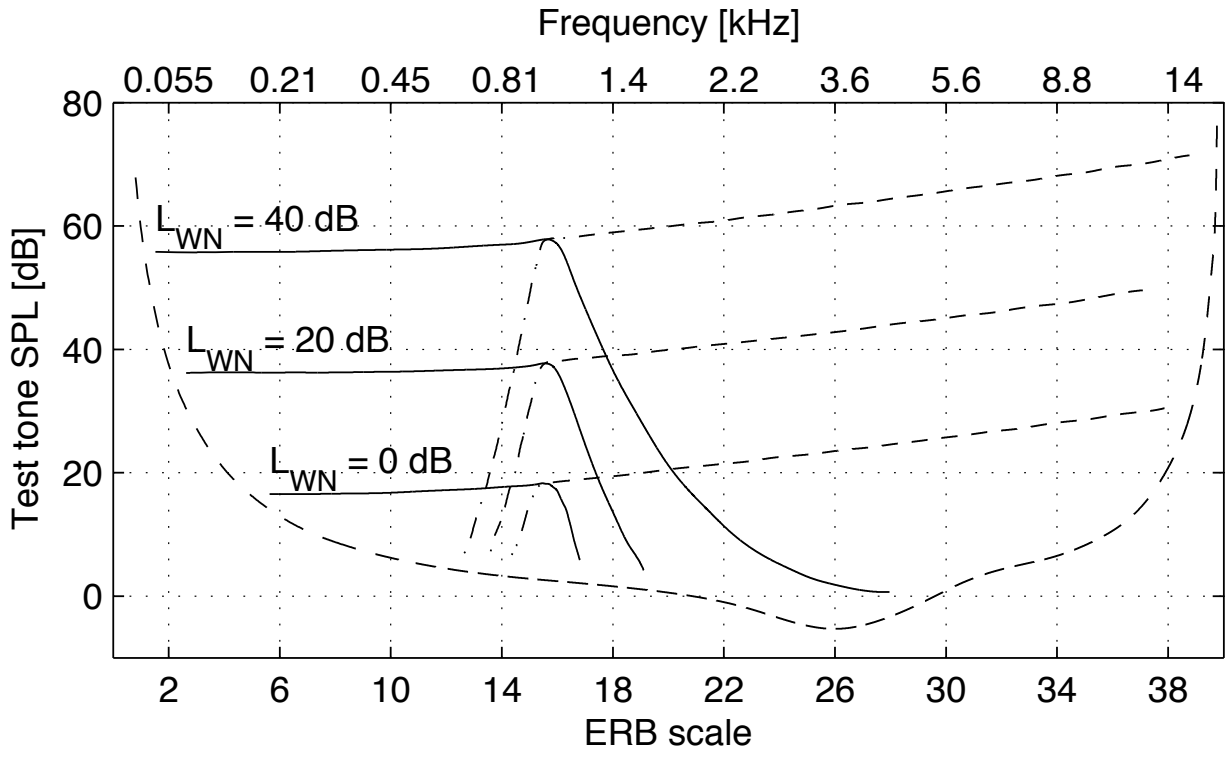
- Masking as function of the level of masker




Adapted from Fastl and Zwicker (2007)

# Frequency masking

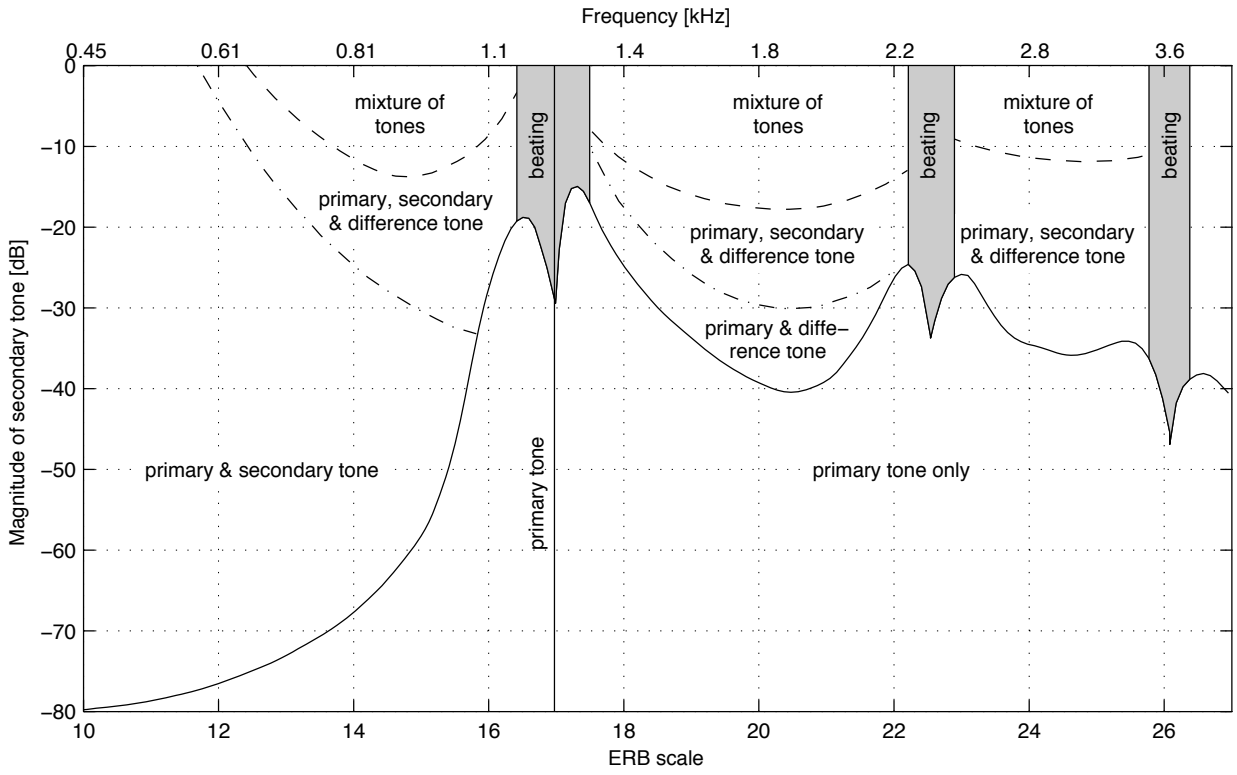
- Frequency masking by lowpass and highpass noise




Adapted from Fastl and Zwicker (2007)

# Frequency masking

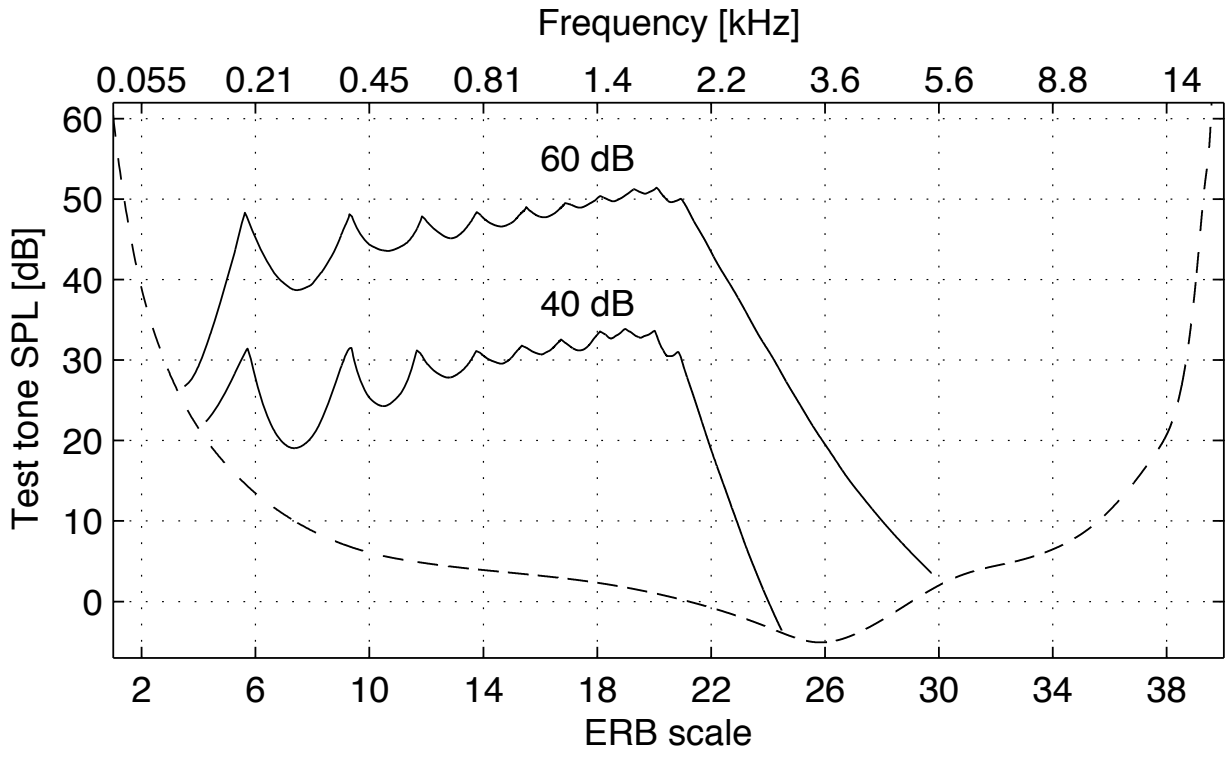
- Frequency masking by 1kHz tone




Adapted from Wegel and Lane (1924)

# Frequency masking

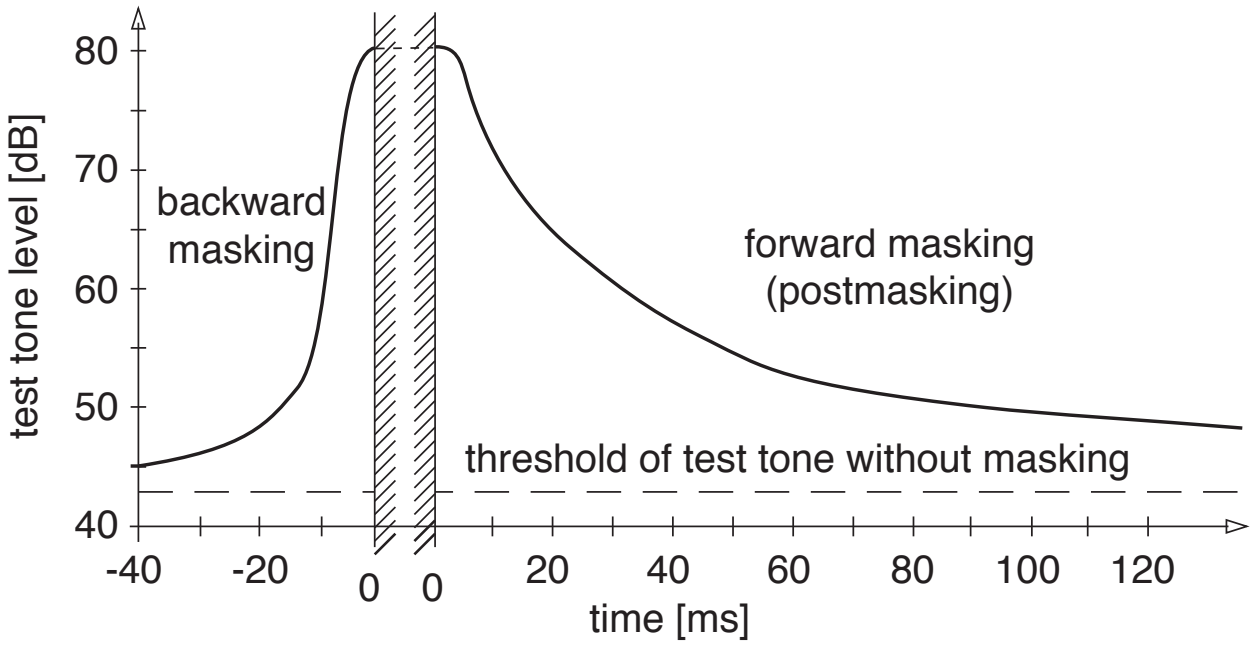
- Frequency masking by harmonic tone complex




Adapted from Fastl and Zwicker (2007)

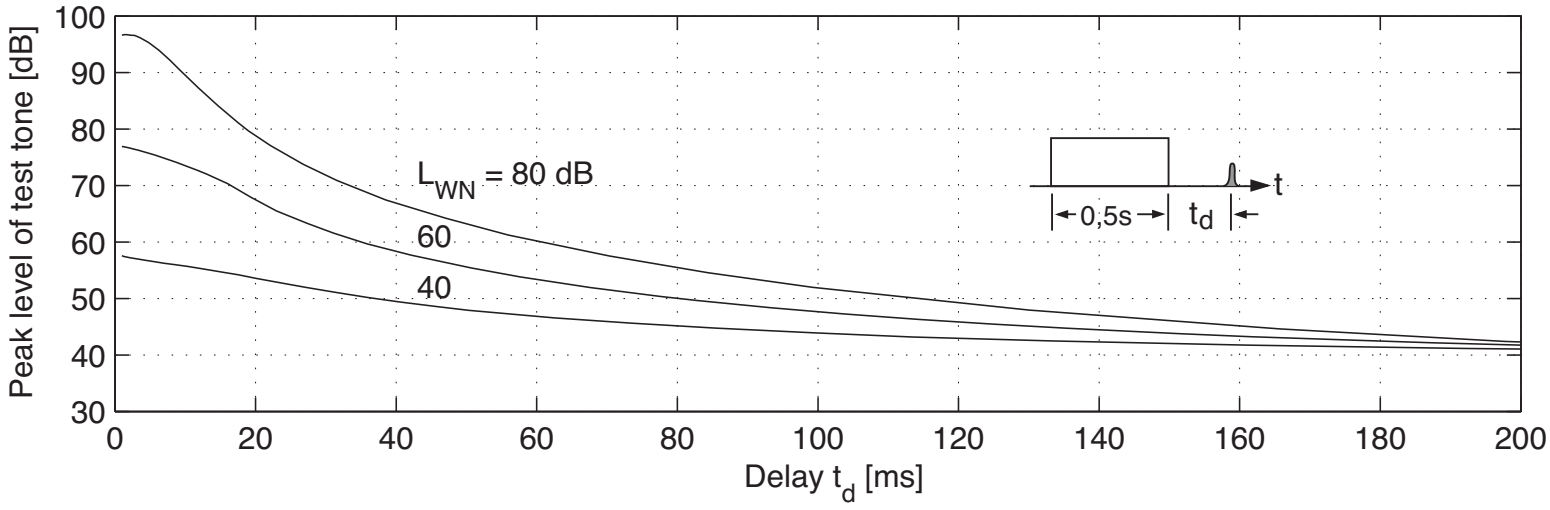
# Temporal masking

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



# Temporal masking

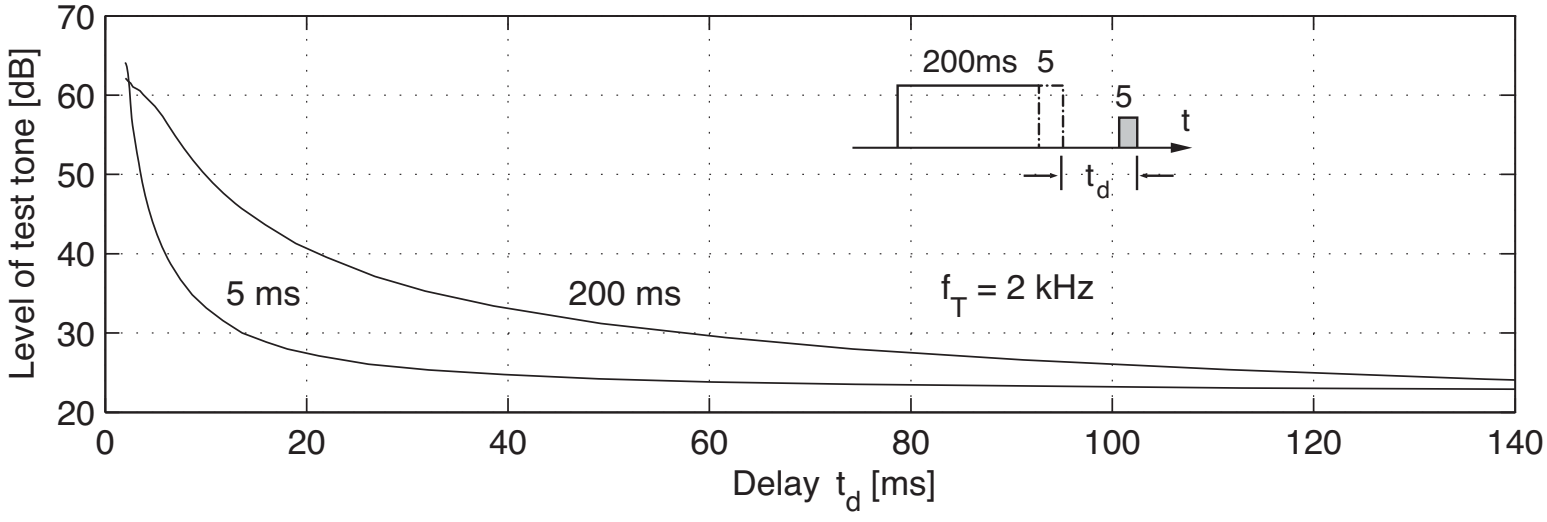
- Forward masking with different masking levels




Adapted from Fastl and Zwicker (2007)

# Temporal masking

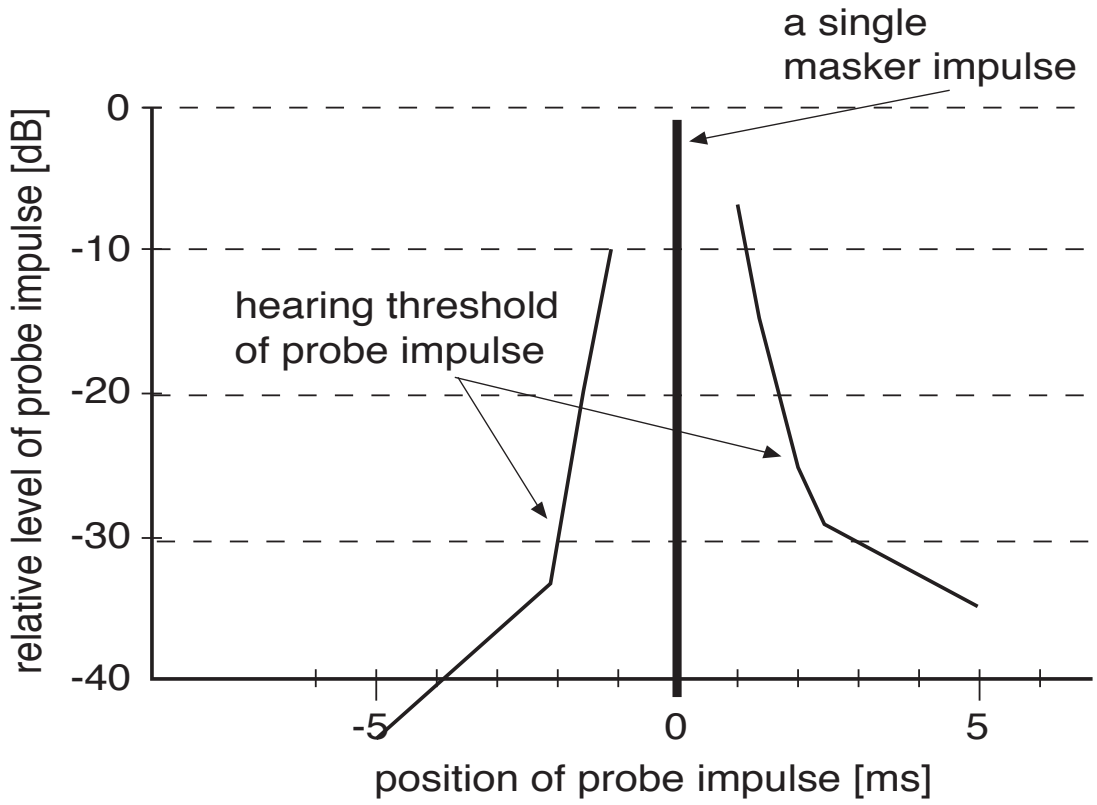
- Forward masking with different lengths of masking noise




Adapted from Fastl and Zwicker (2007)

# Temporal masking

- Masking by an impulse



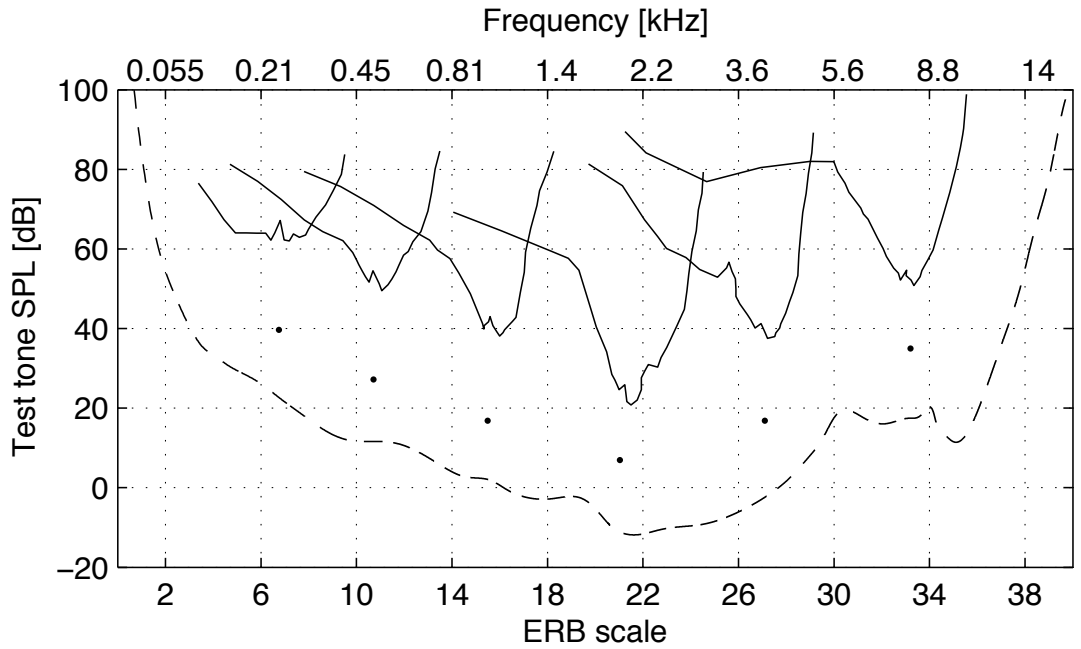

Adapted from Feth and O'Malley (1977)

# 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

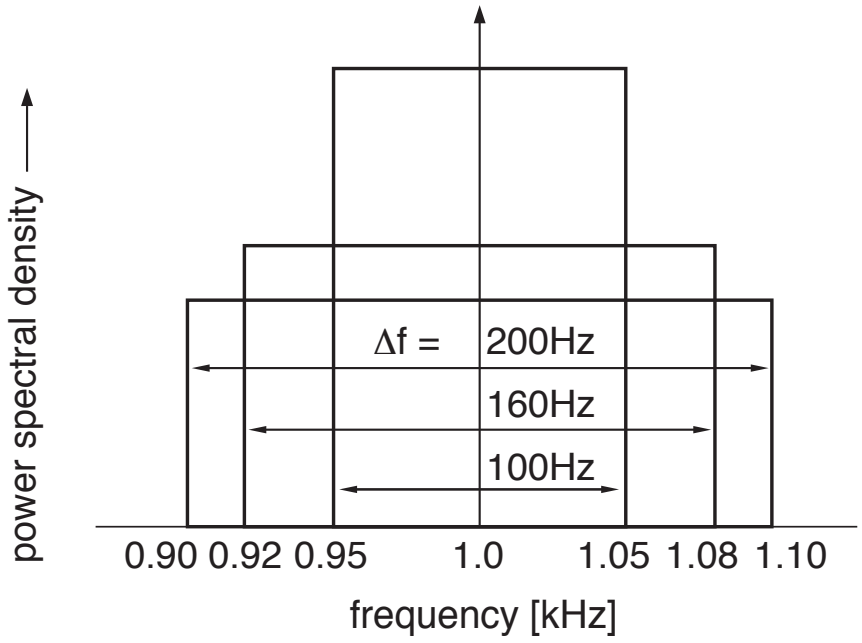
- Psychophysical tuning curves
- Masking threshold - low-level sinusoid as signal and narrowband noise as masker




Adapted from Vogten (1974)

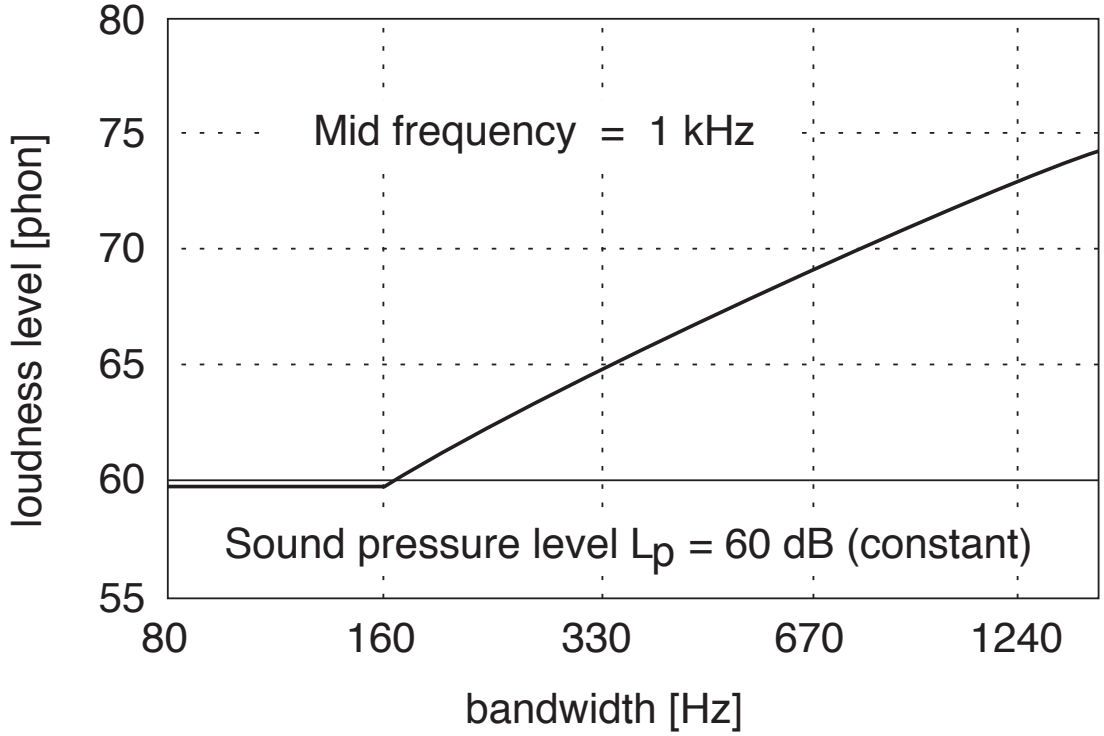
# Measuring the width of critical bands

- Experiment: loudness vs. bandwidth of noise



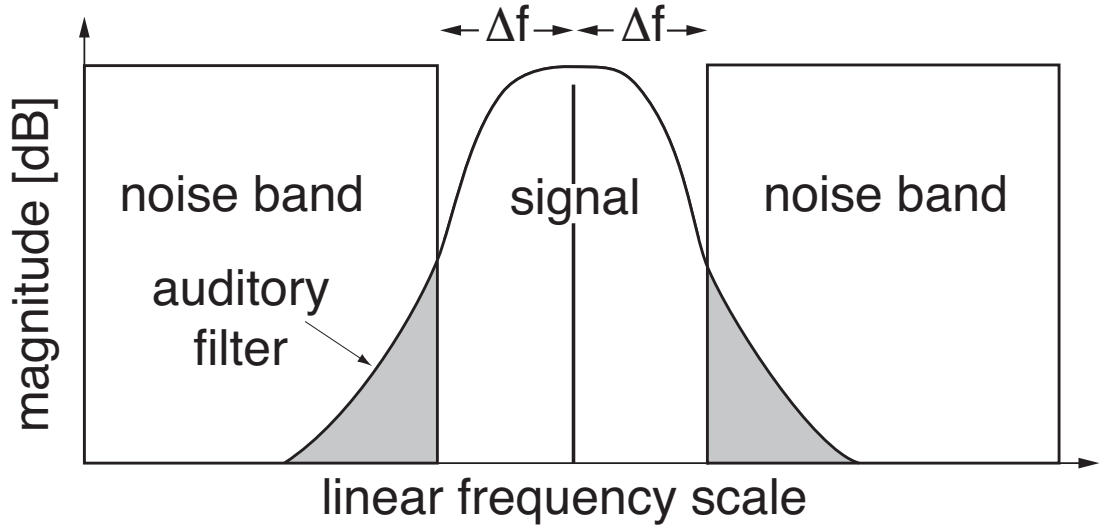
# Measuring the width of critical bands

- Loudness increases when the banwidth increases the critical bandwidth



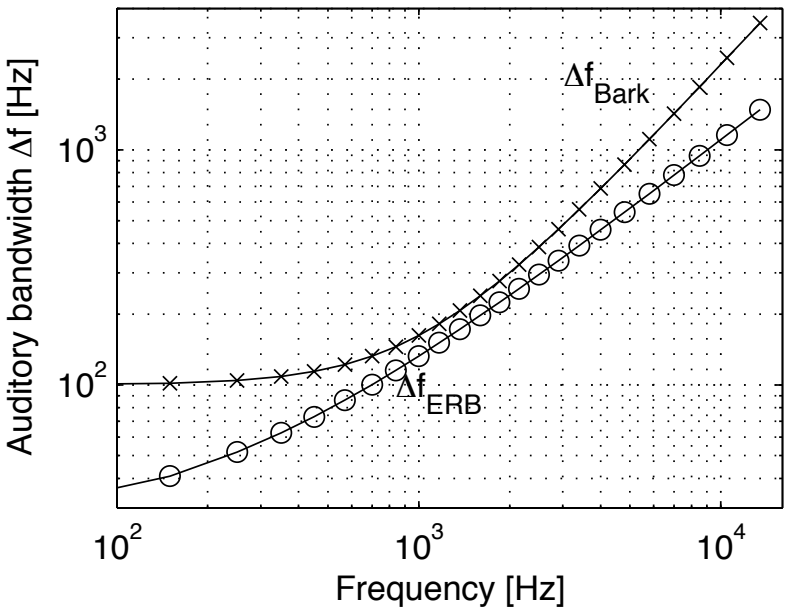
# Measuring the width of critical bands

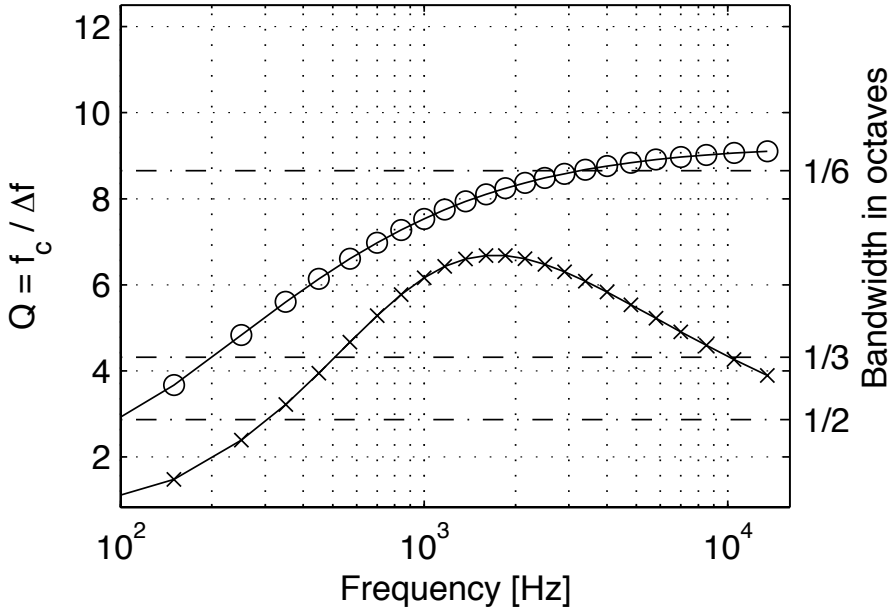
- Masking threshold of the signal is measured as function of the width of passband
- Equivalent rectangular bandwidth scale (ERB scale)



# Width of critical bands

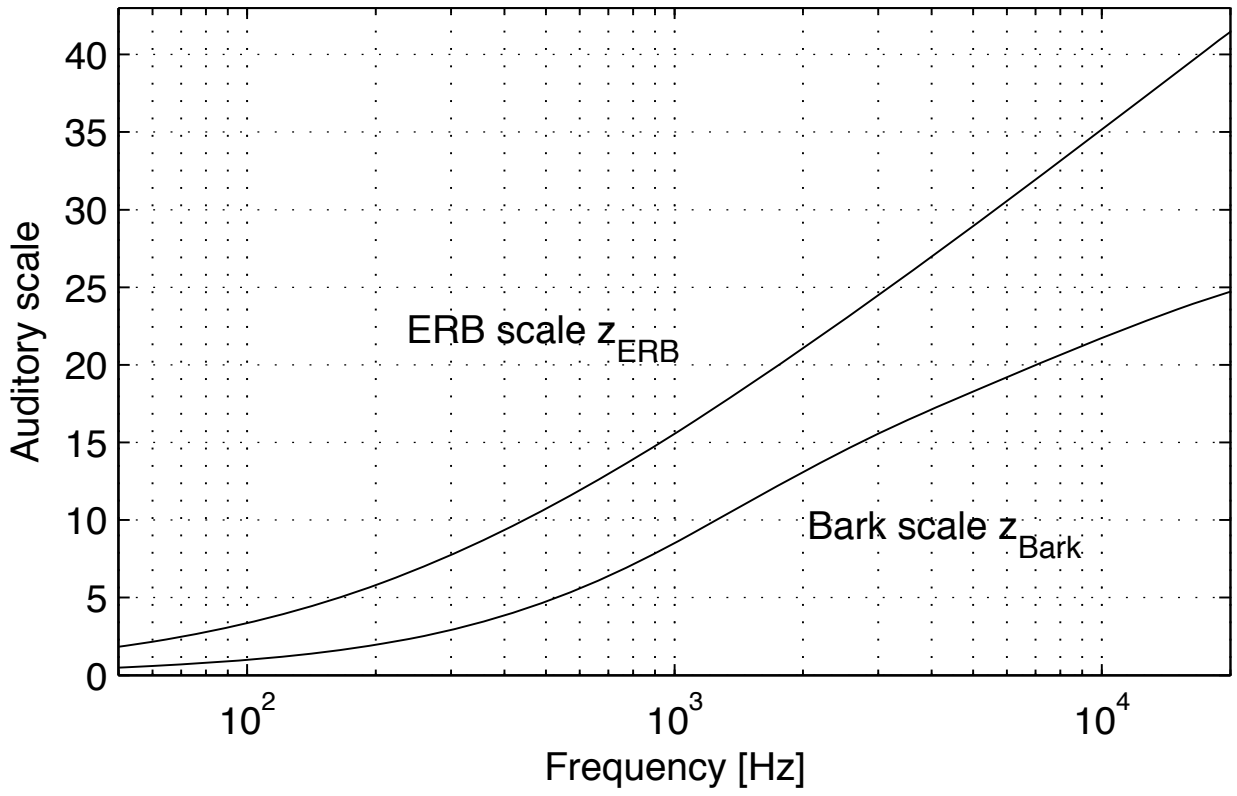
- Bark and ERB dependence on frequency



# 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.