

Towards an Efficient Method to Derive the Phase Response for Hearing-Impaired Listeners

Katharina Zenke, Bernhard Laback, Hisaaki Tabuchi

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Human Phase Response

Phase Response: Frequency-dependent phase filtering in the cochlea

Masker-phase effect: up to 25dB differences in masking depending on the masker's relative phases Kohlrausch and Sander (1995); Oxenham and Dau (2004)

Important Mechanism:

- Peakedness of „internal“ masker representation
- Cochlear compression

→ Listeners with cochlear hearing impairment show less masker-phase effect, likely due to lack of cochlear compression
Oxenham and Dau (2004)

→ Alternative paradigm:
Based on interaural time differences (ITDs) in the signal envelope Lacher-Fougère and Demany (2005)

Estimation of the phase response based on ITD cues

Basic idea:

- Envelope ITD sensitivity depends on the temporal shape of the “internal” signal representation
Laback et al. (2011); Klein-Hennig et al. (2011); Bernstein and Tratiotis (2009)
- Variation of *signal* phase response: Strongest ITD cue expected for condition with most peaky internal envelope
- Provides indirect measure of *cochlear* phase response

ITD thresholds: Data collected so far show systematic effect of phase on ITD thresholds (see talk PD130 by Tabuchi et al.)

- too time consuming
- alternative method?

Ways to measure the strength of ITD cues?

Hypothesis: **ITD-based extent of laterality depends on the signal's phase relations**

Expectation: Peaky “internal” signal representation
→ large extent of laterality

Hypothesis: **Apparent source width depends on the signal's phase relations**

Expectation: Peaky „internal“ signal representation
→ Compact apparent source width

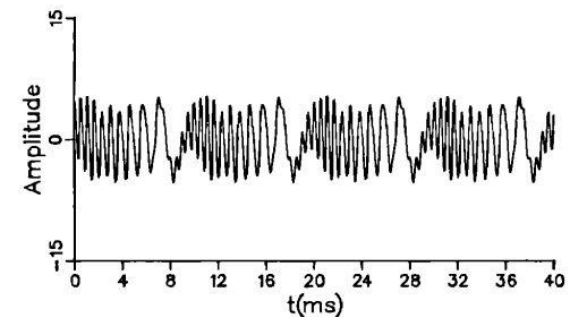
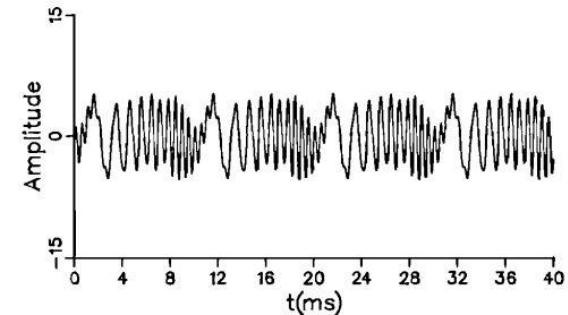
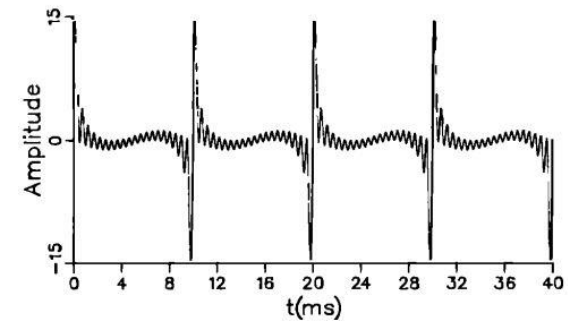
Stimuli

Schroeder-phase harmonic complexes

- Constant long-term power spectrum
- Variable phase curvature
- Variable crest-factor \rightarrow peakedness

Parameters:

- 13 harmonics from 3400 to 4600 Hz
- Fundamental frequency: 100 Hz
- Phase curvature C: nine values from -1 to 1



Kohler and Sander (1995)

Experiment 1: Lateralization (1)

Aim: Measure extent of laterality for different phase conditions

Procedure: Pointing task Bernstein and Trahiotis (2011), Dietz et al. (2015)
ILD pointer matched in extent of laterality to targets

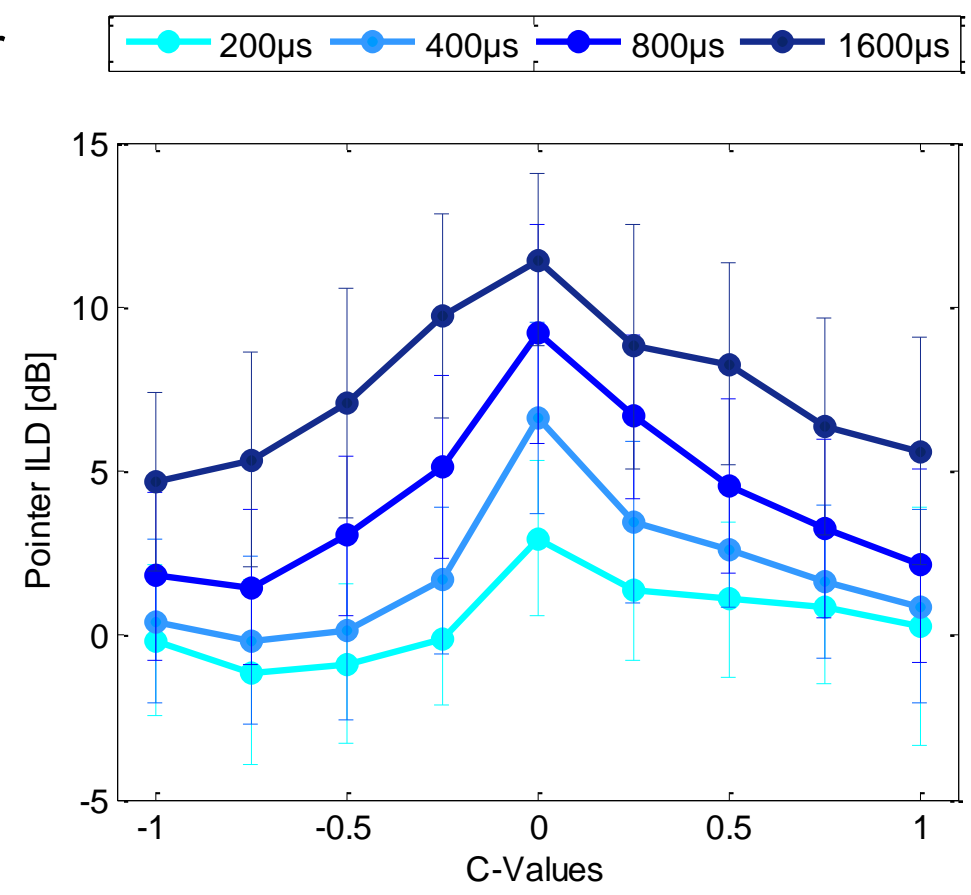
- Target stimuli: Schroeder-phase signals with ITD = 200, 400, 800 and 1600- μ s ITD Mossop and Culling (1998), Dietz et al. (2015)
- Pointer stimulus: Narrow-band noise with variable ILD
- Subjects: 8 normal-hearing listeners
- Level: 70 dB SPL

Experiment 1: Lateralization (2)

Results:

- Lateralization higher for low phase curvatures
- Effect of phase curvature up to 7dB
- Same results for supra-natural ITD value
- Similar variance in all conditions

Mean ILD values for different target signals



Effect of phase response on loudness (1)

Procedure:

Adaptive double staircase Jesteadt 1980

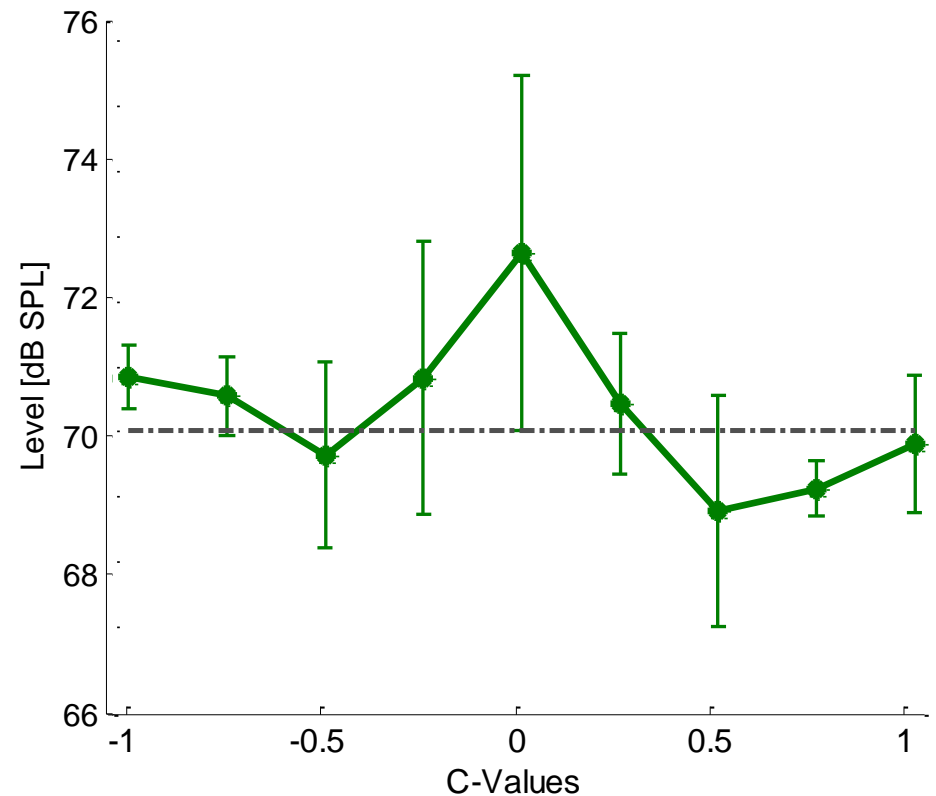
3-down-1-up task

- Loudness matching of all Schroeder-phase signals with reference Schroeder-phase signal ($C = 1$, SPL = 70 dB)

Effect of phase response on loudness (2)

Results:

- Loudness differs up to 4 dB
- Signals with small phase curvatures (= large peakedness) require higher level → lower loudness



Experiment 2: Apparent source width (1)

Aim: Measure apparent source width for different phase conditions

Procedure: Constant stimuli method

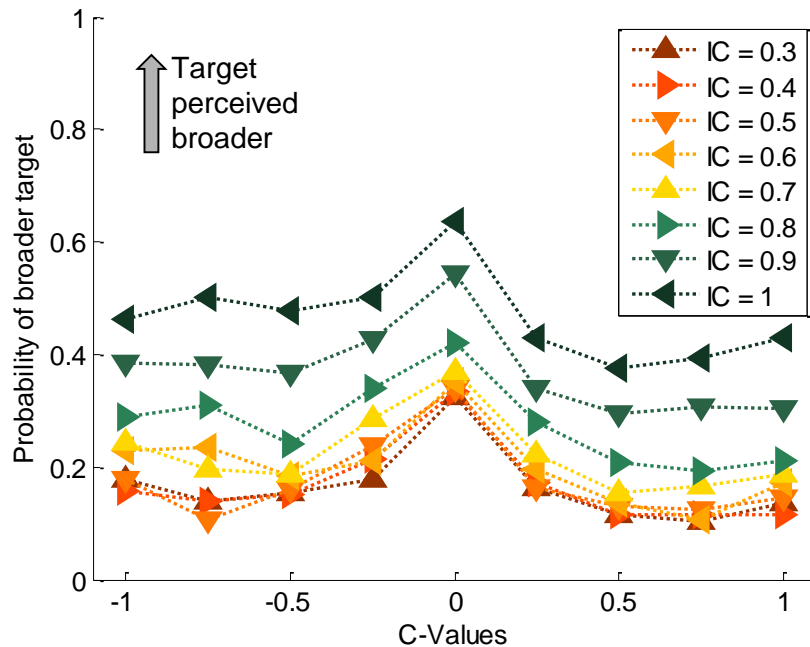
Comparison of source width of Schroeder-phase targets and reference noise stimuli

- Target stimuli: Schroeder-phase signals
- Reference stimuli: Narrow-band noises with varied interaural correlation (IC) from 0.3 to 1
- Subjects: 6 normal-hearing listeners
- Loudness adjusted according to pretest

Experiment 2: Apparent source width (2)

Results:

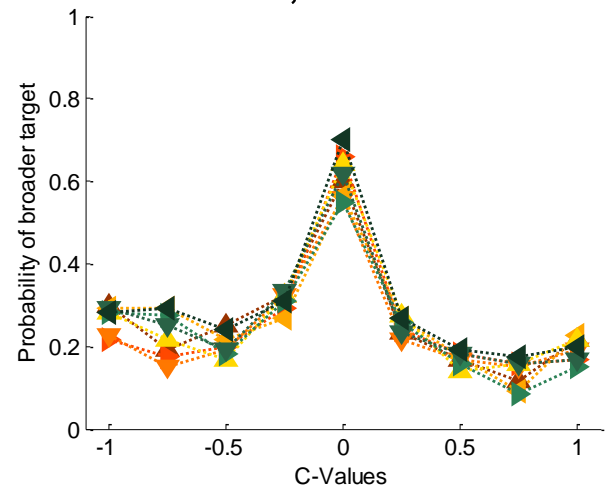
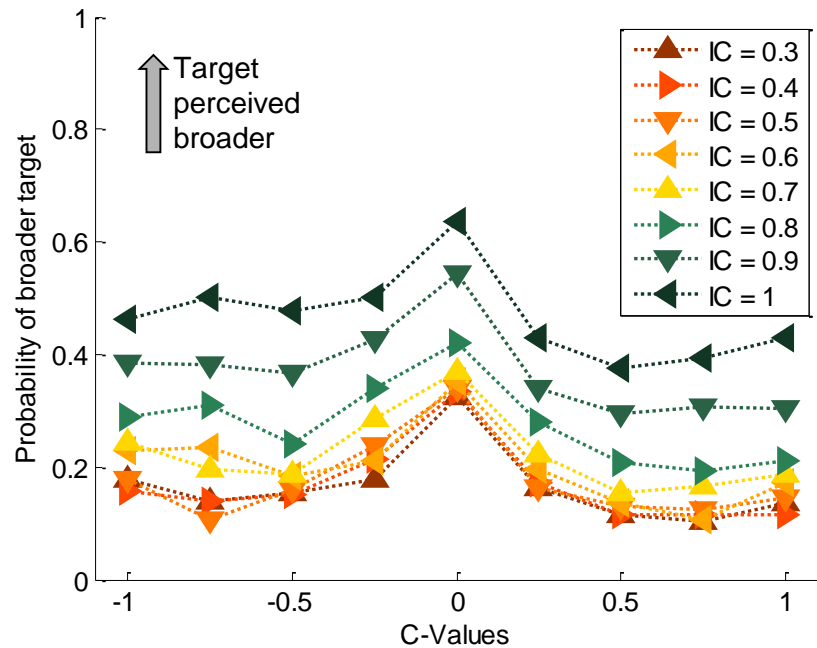
- Means: effect of C and IC on the source width, but...



Experiment 2: Apparent source width (2)

Results:

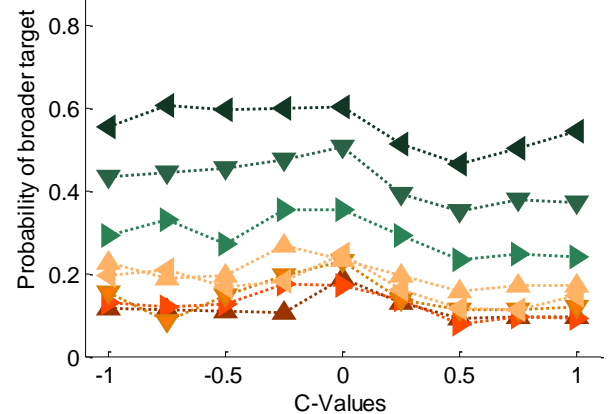
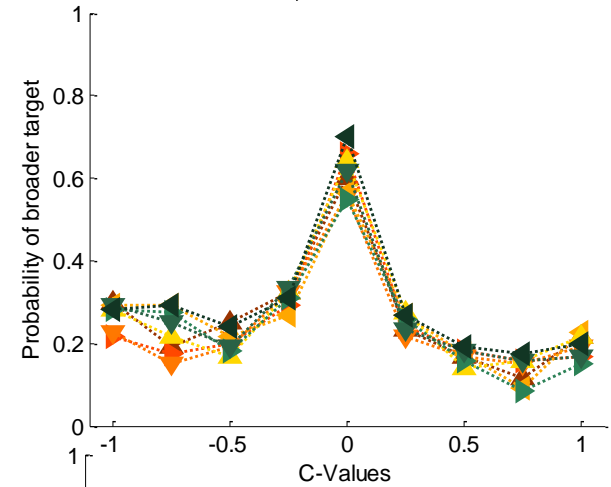
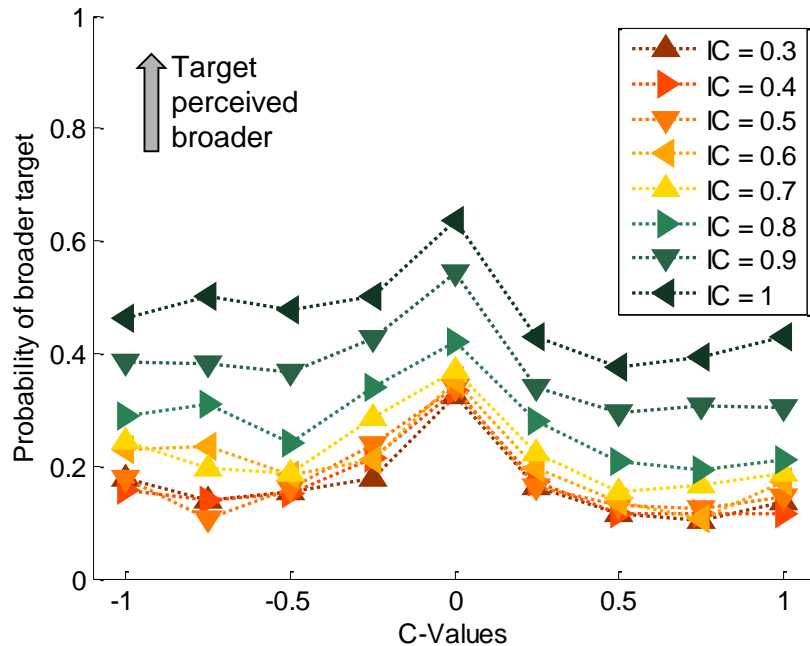
- Means: effect of C and IC on the source width, but...
- 2 subjects show effect of C but no effect of IC



Experiment 2: Apparent source width (2)

Results:

- Means: effect of C and IC on the source width, but...
- 2 subjects show effect of C but no effect of noise IC
- 4 subjects show effect of IC but only a very small effect of C



Summary & Conclusion

- Phase relations have strong effect on ITD-based **extent of laterality**
- Signals with smaller phase curvature have smaller **loudness**
- No consistent effect of phase relations on **apparent source width** (for narrow-band stimuli)
- The ITD-based lateralization method could be used to estimate the phase response of hearing impaired listeners

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