New measurement methods for signal adaptive hearing aids

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Motivation

- modern hearing aids signal processing is signal adaptive
  ➔ nonlinear and time variant
    - compression
    - time constants
    - adaptive algorithms (classification, noise reduction, adaptive directionality)
- Behaviour for arbitrary nonstationary signals can not be predicted from stationary.
- Impact of parameter variations on auditory perception can not be quantified.

==> New analysis methods necessary !

Requirements for new analysis methods

- psychoacoustical / audiological relevance
  ==> properties of human auditory system
- assessment of all hearing aid features
  ==> arbitrary (natural) input signals
- easy-to-understand visualisation
  ==> use of well-known diagrams

==> PAsHA

(„Perceptual Assessment of Hearing Aids“)

PAsHA: Perceptual Assessment of Hearing Aids

- Aurally adequate analysis of hearing aid input and output signals:

  critical band level percentile pattern

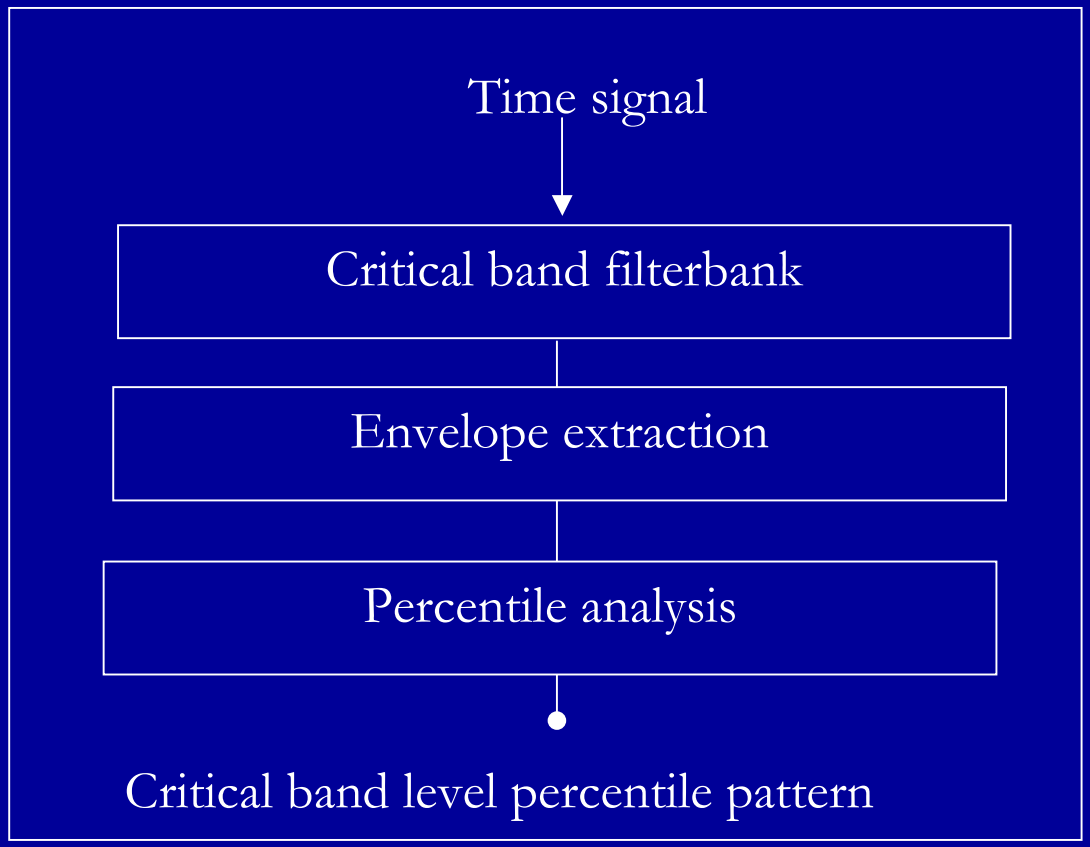
- Technical parameters:

  effective gain, effective compression ratio, effective I/O curve

- Psychoacoustic parameters:

  Specific loudness, loudness, sharpness, fluctuation strength, speech intelligibility

Aurally adequate analyis of hearing aid input and output signals



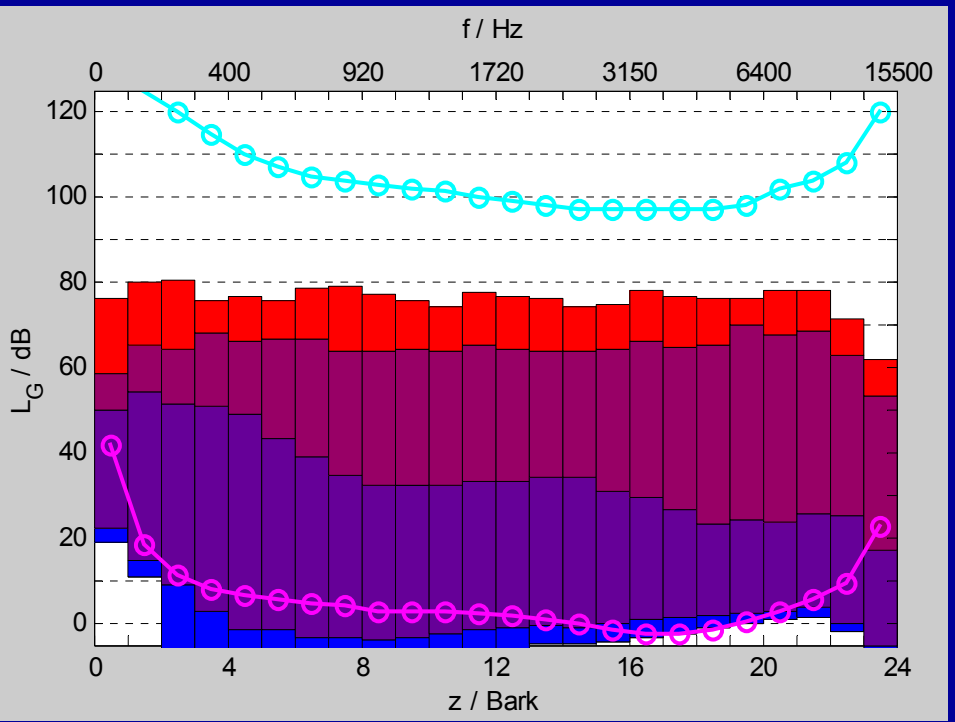
FTT 4th order / Gammatone filterbank

Auditory temporal window (ERD = 8 ms, f_S = 500 Hz)

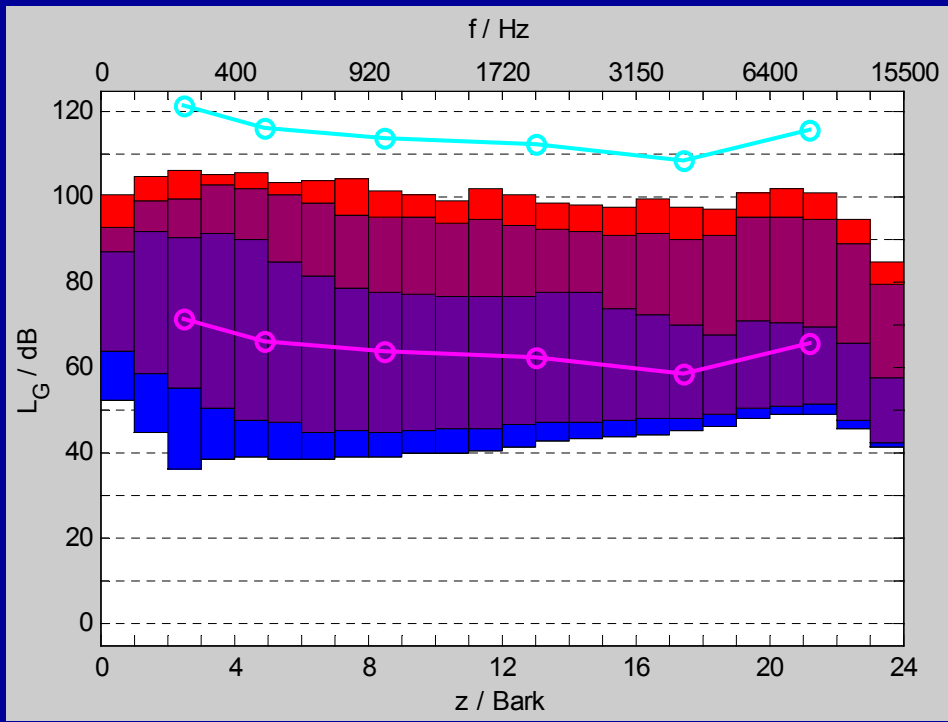
Percentiles in all critical bands

Critical band level percentile patterns

Hearing aid input signal



Hearing aid output signal



Test signal: speech with door slamming

„hearing aid“: 16-channel-compression, syllabic compression, DSL

1% / 5% / 50% / 95% / 99% percentiles displayed

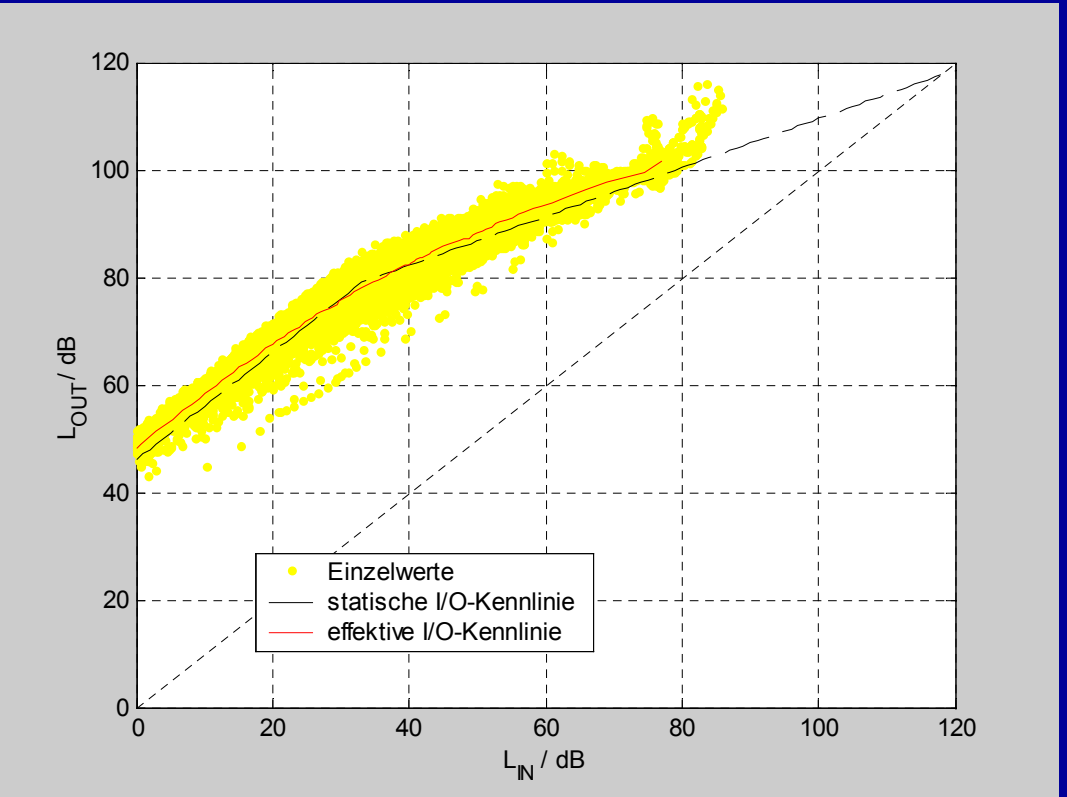
Technical parameters I

Effective compression ratio:

$$CR_{eff} = \frac{1}{24}\sum_{z=1}^{24}\frac{L_{I95}(z) - L_{I5}(z)}{L_{O95}(z) - L_{O5}(z)}$$

Effective I/O-curve:

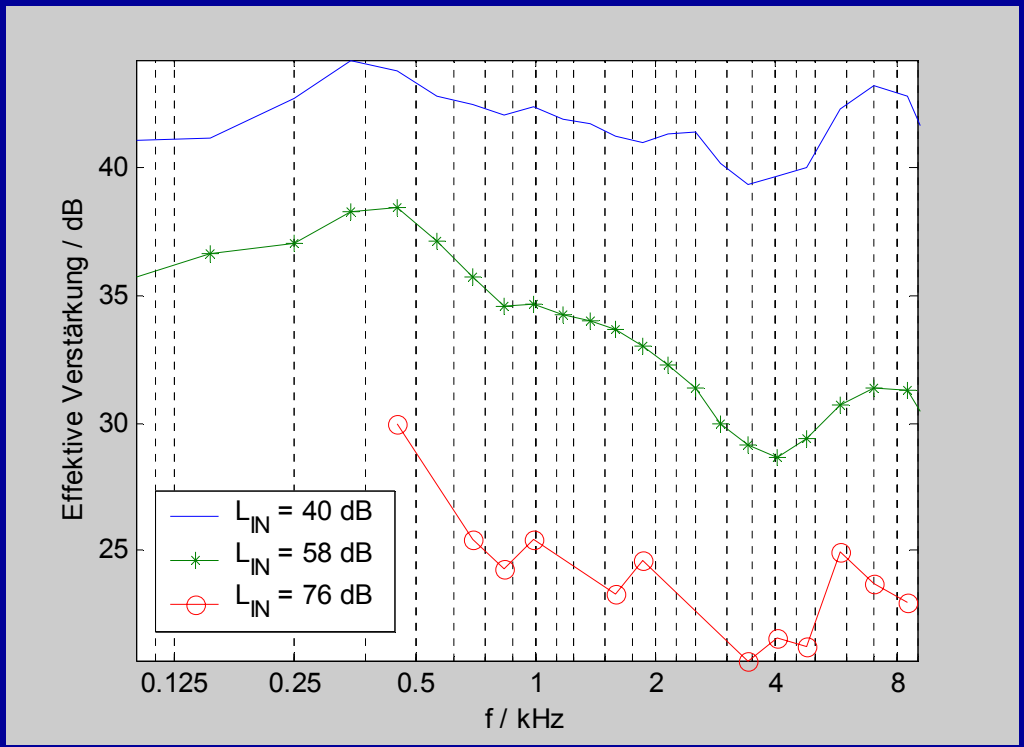
- Form for each percentile x a pair of variates with L_{Ix} und L_{Ox}
- Enter this pair of variates into the L_{IN}/L_{OUT}- diagram



Technical parameters II

Effective gain:

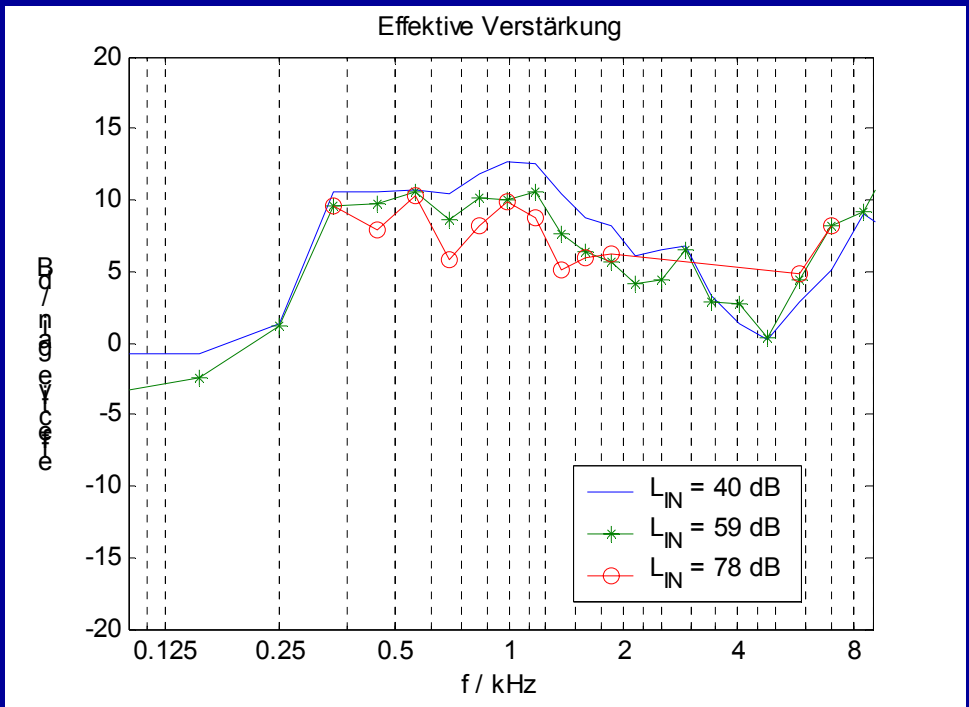
- Determine the percentile x of the input signal for a specified level L_{Ix} (e.g. 40 / 58 / 76 dB)
- Determine the level of the same percentile of the output signal L_{Ox}
- Effective gain is: $L_{ox} - L_{Ix}$



Technical parameters III

Differential gain:

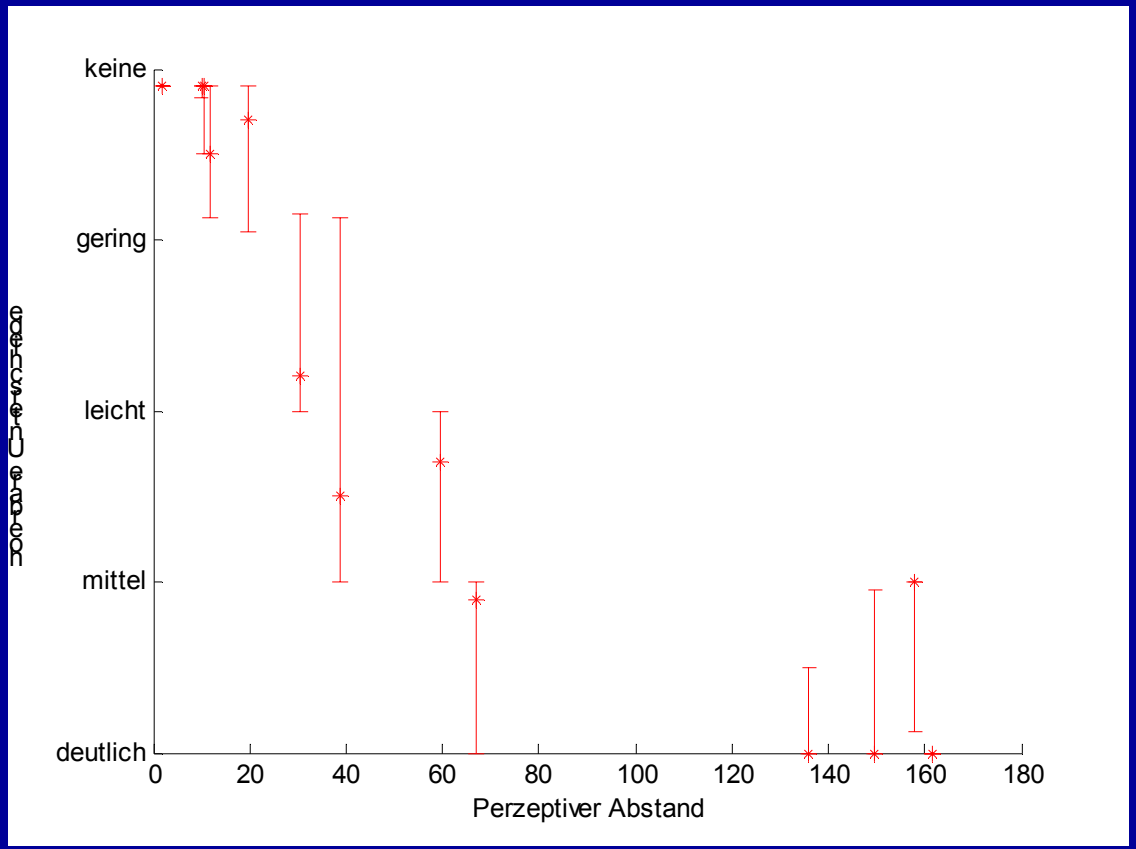
Difference of effective gains: hearing A - hearing aid B



Perceptual relevance

Subjective data vs. Calculated „perceptual distance“

„perceptual distance“: euclidian distance of effective gains



distance < 1 dB:
no audible differences

Increasing perceptual distance results in increasing subjective difference

outlook: calculate perceptual distance from specific loudness

Psychoacoustic Parameters

Specific loudness:

- prerequisite: loudness model for normal and hearing-impaired listeners (e.g. DLM)
- transform „critical band level percentile pattern“ into „specific loudness percentile pattern“ by applying individual loudness function $N'(L_E)$

Loudness:

N = sum over all 95%-percentiles of Specific loudness percentile pattern

Sharpness:

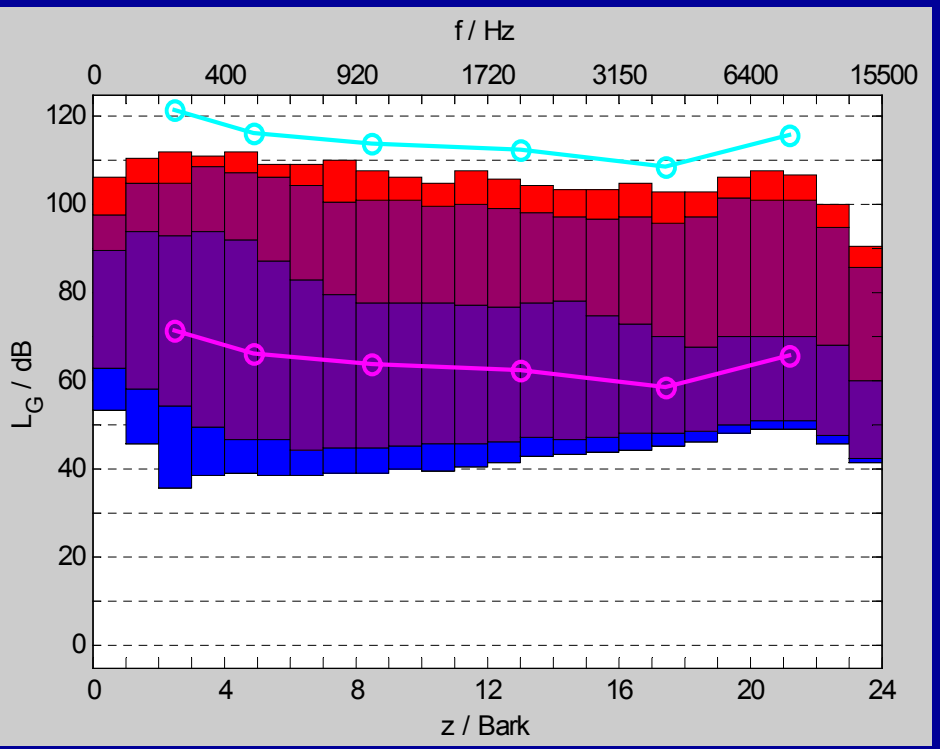
S = weighted sum over all 80%-percentiles of Specific loudness percentile pattern

Speech intelligibility:

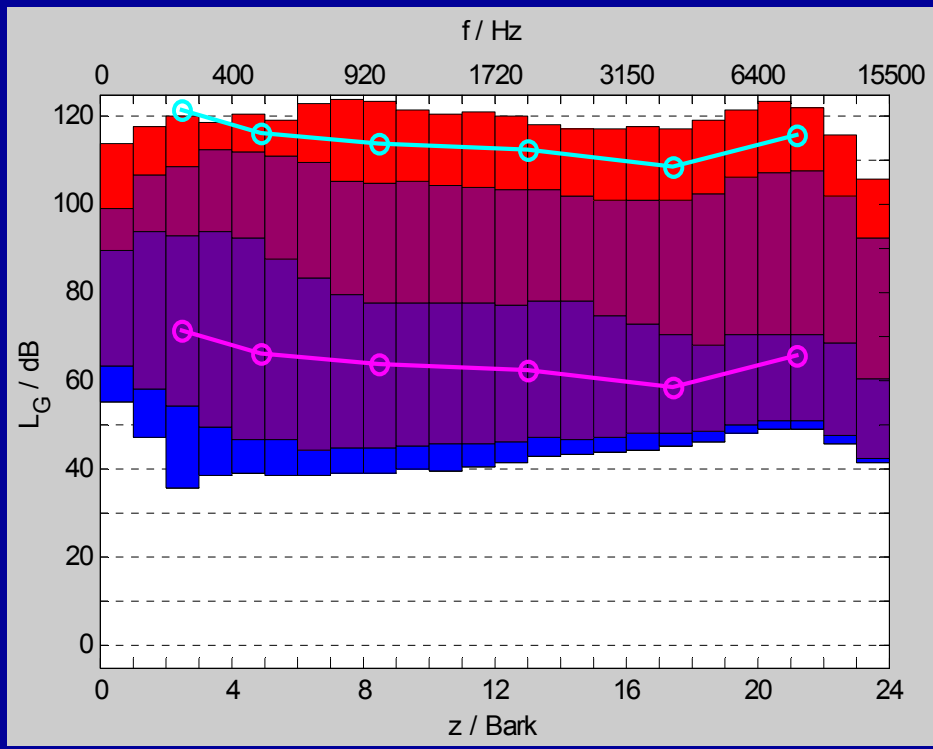
AAI (requires effective compression ratio!) and SII can be calculated from critical band level percentile pattern of speech and noise

Example: impact of compression time constants I

Dual AGC



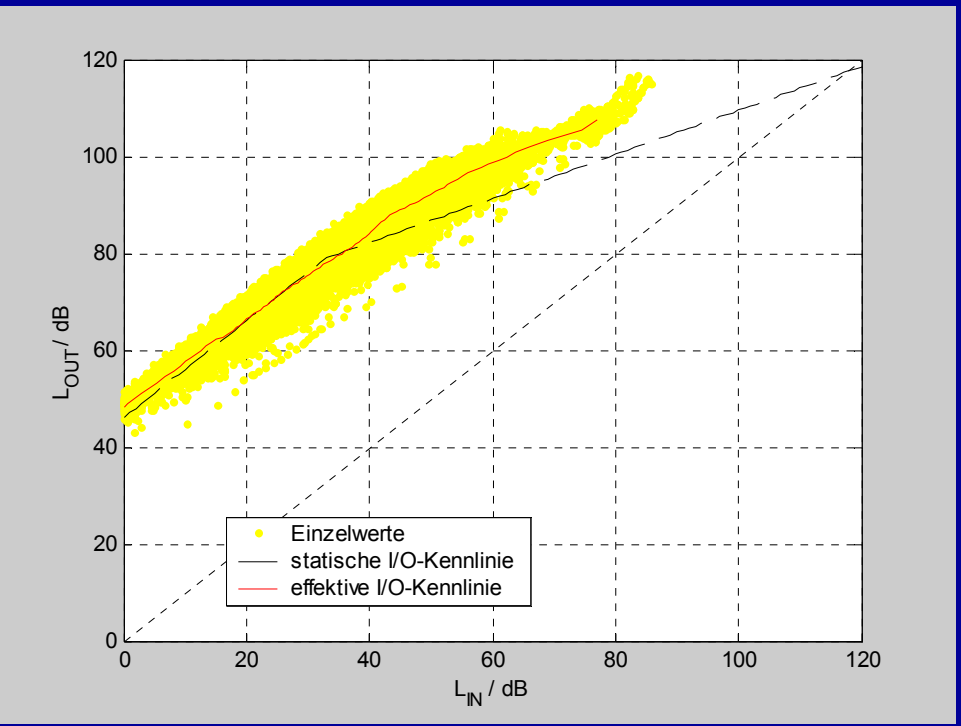
AVC



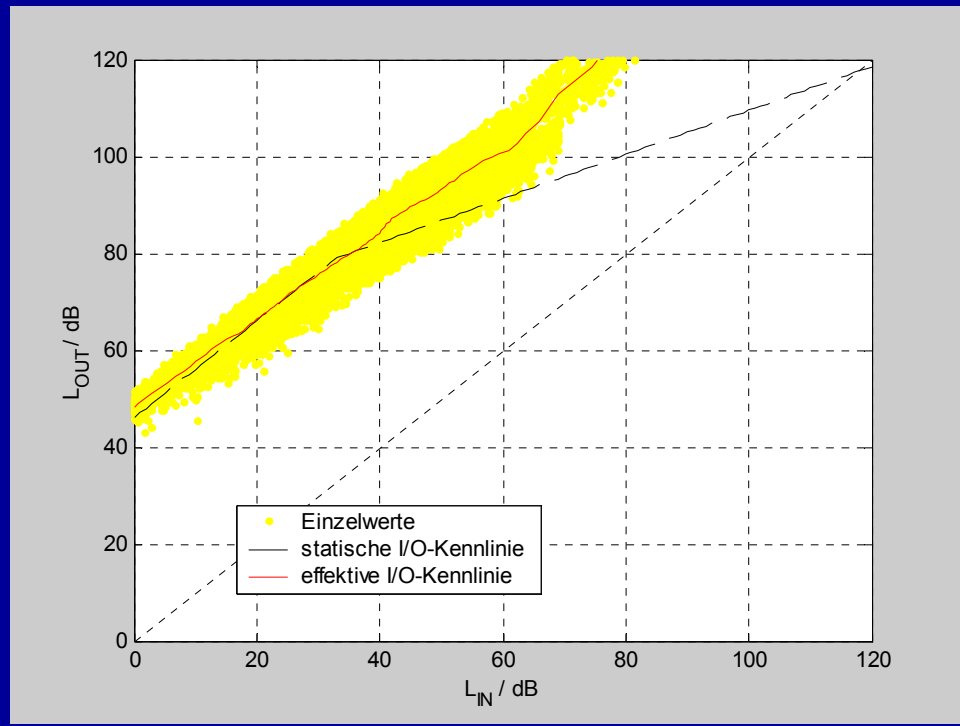
- 50% percentile (average level) similar
- AVC: high levels exceed UCL !

Example: impact of compression time constants II

Dual AGC



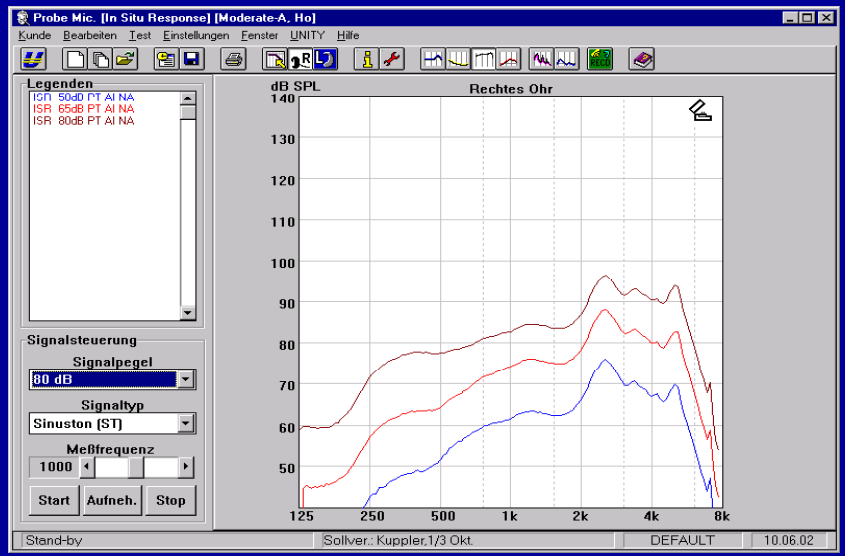
AVC



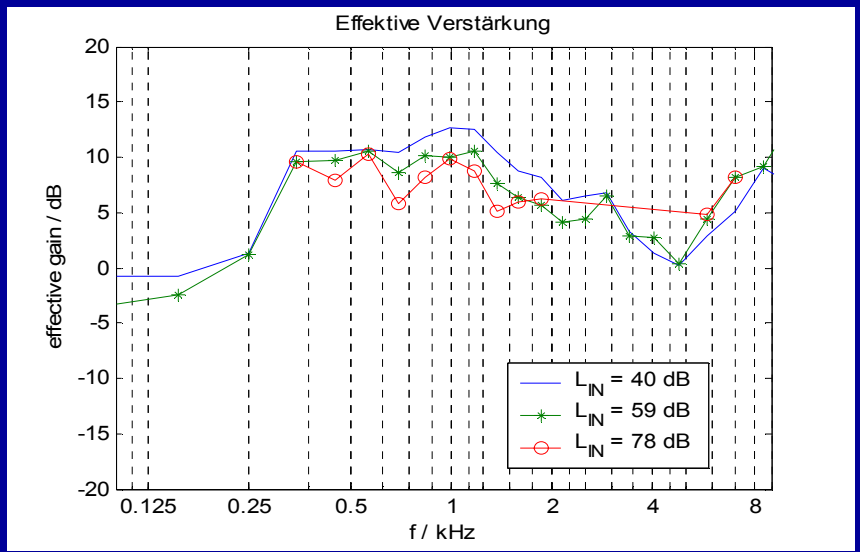
Effective I/O-curves:

nearly no compression with AVC !

Example: comparison of advanced hearing aids



Large differences of compression characteristics revealed in 2ccm measurements



Only a linear offset observed for effective gain (in line with subjective judgements)

Summary of PAsHA

PAsHA: Method for perceptual analysis of nonlinear and adaptive hearing aids

- takes into account properties of the human hearing system: HTL, UCL, temporal and spectral resolution
- Calculation of psychoacoustic parameters
  ==> psychoacustic / audiological relevance
- Calculation of technical parameters
  ==> well-known diagrams can be used (easy-to-understand)
- arbitrary (natural) signals can be used
  ==> all hearing aid features can be assessd

Discussion

- New measurement methods are necessary for modern hearing aids
- Specification of requirements
- Selection / development of measurement method(s)

➔ Proposals for requirements and methods are available (Verschuure et al., Leijon, PAsHA...)

➔ Selection and implementation must be supported by hearing aid manufacturers (joint research project?)