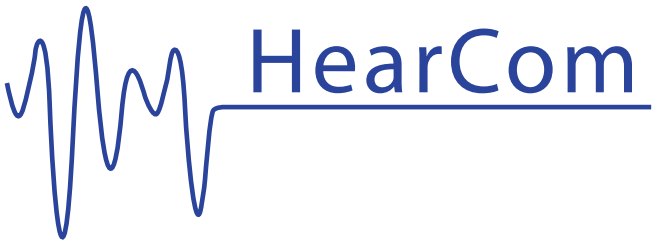
Signal Processing for Hearing Instruments

Arne Leijon and many HearCom partners

Workshop Hearing Screening and Technology, Brussels 28 Jan 2009



KTH Electrical Engineering

HearCom Signal Enhancement Approaches

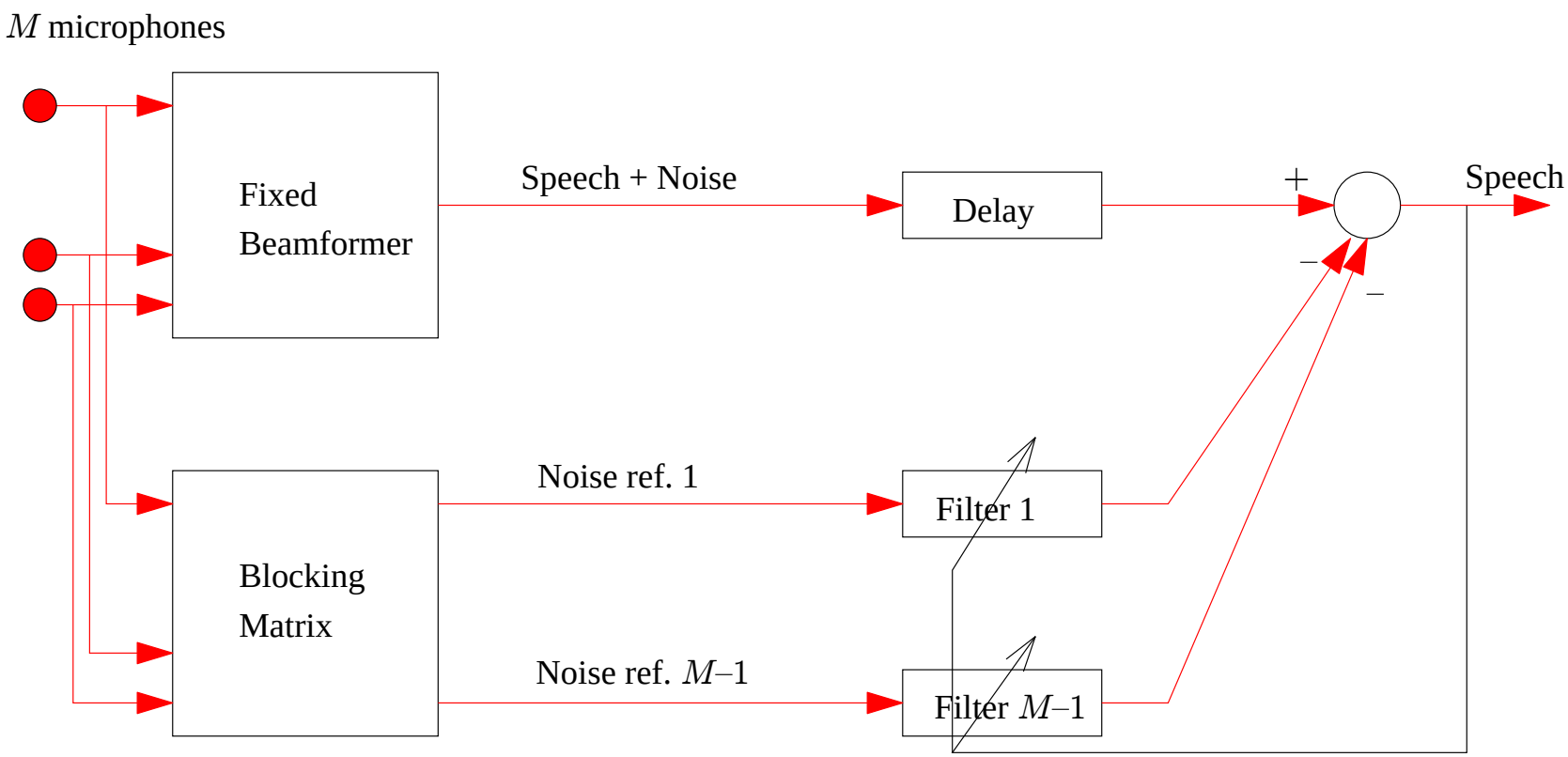
- Multi-microphone Noise Reduction
  - Speech and Noise from different spatial directions
- Single-channel Noise Reduction
  - Speech and Noise with different signal properties
- Feedback/Whistling suppression

HearCom Algorithm Development and Evaluation

- 2005:
  - Inventory, many algo's on PC platform, not real-time
  - Initial evaluation, normal hearing
- 2006:
  - Selected/Improved algorithms, not real-time
  - Preliminary evaluation, simulated hearing impairment
- 2007:
  - Optimization for real-time, low processing delay
  - Selected versions implemented on real-time platform
- 2008: Final Evaluation, hearing-impaired listeners

Adaptive Beamforming

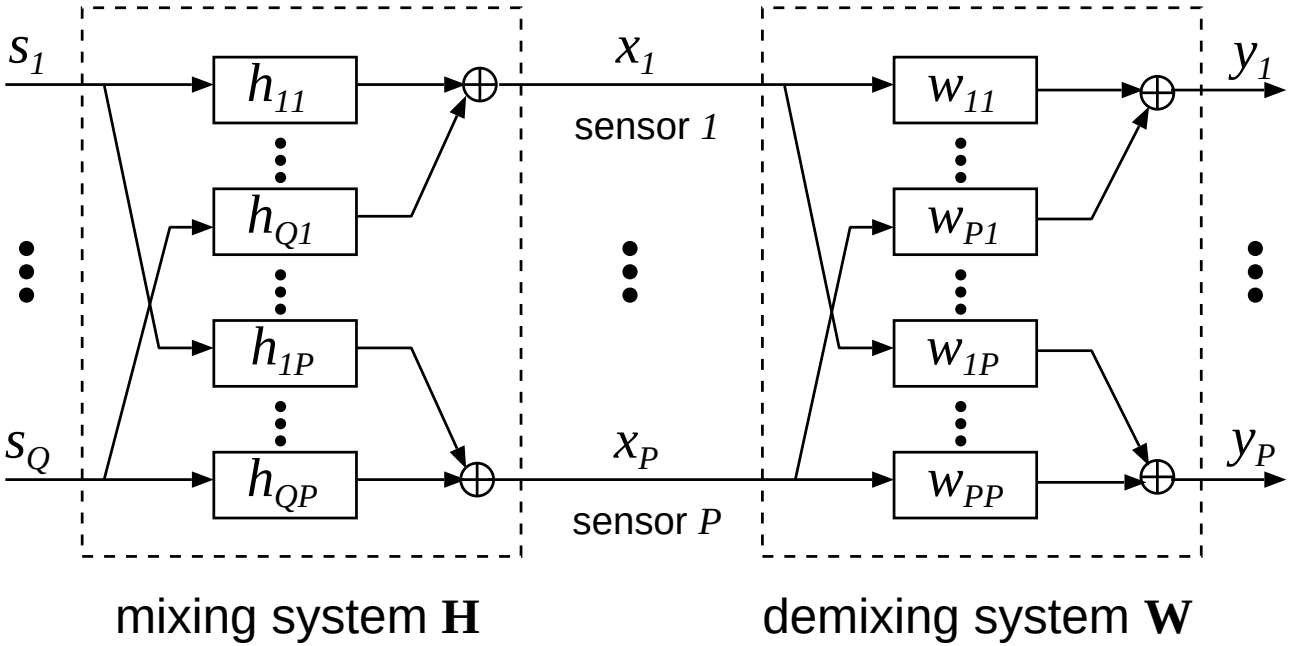
Speech-distortion-weighted multichannel Wiener filter



Adaptation minimizes a weighted sum of residual noise and speech distortion energy.

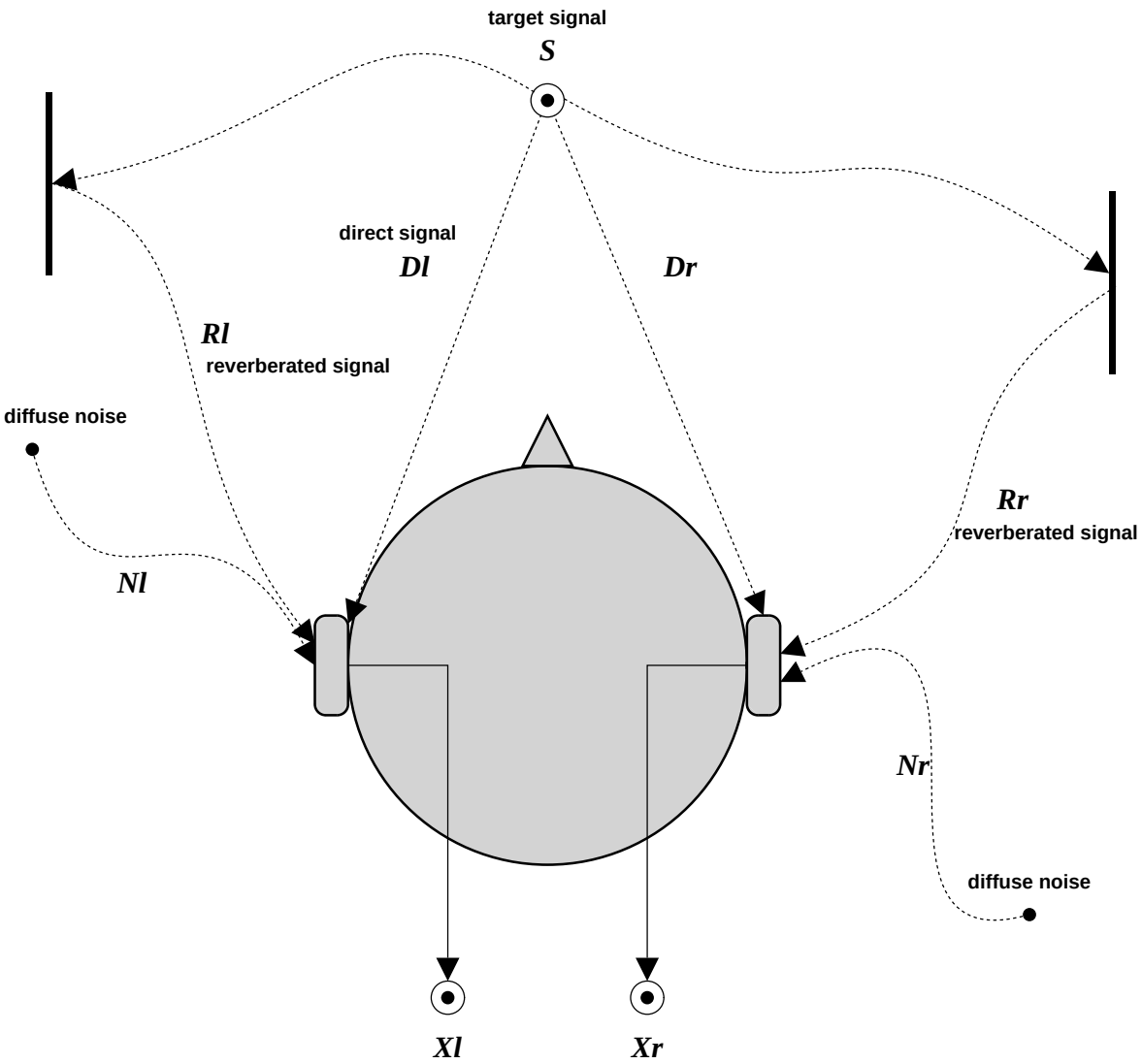
Blind Source Separation

Broadband, 2nd-order statistics. Buchner et al., 2005; Aichner et al., 2006



- Q independent sources, mixed into P microphones.
- Adapt demixing filters to
  - minimize correlation between output signals,
  - without coloring the separated signals.
- HearCom: $Q = P = 2$ microphones, suppress 1 noise source.

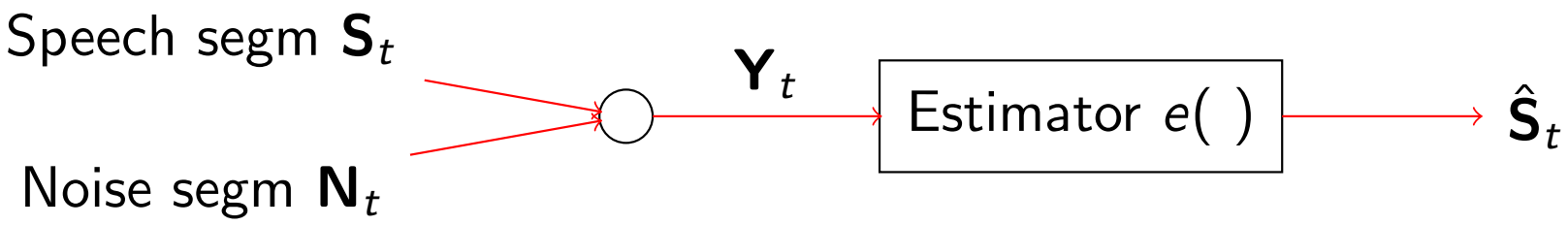
Bilateral Coherence – Dereverberation/Noise Reduction



Gain response

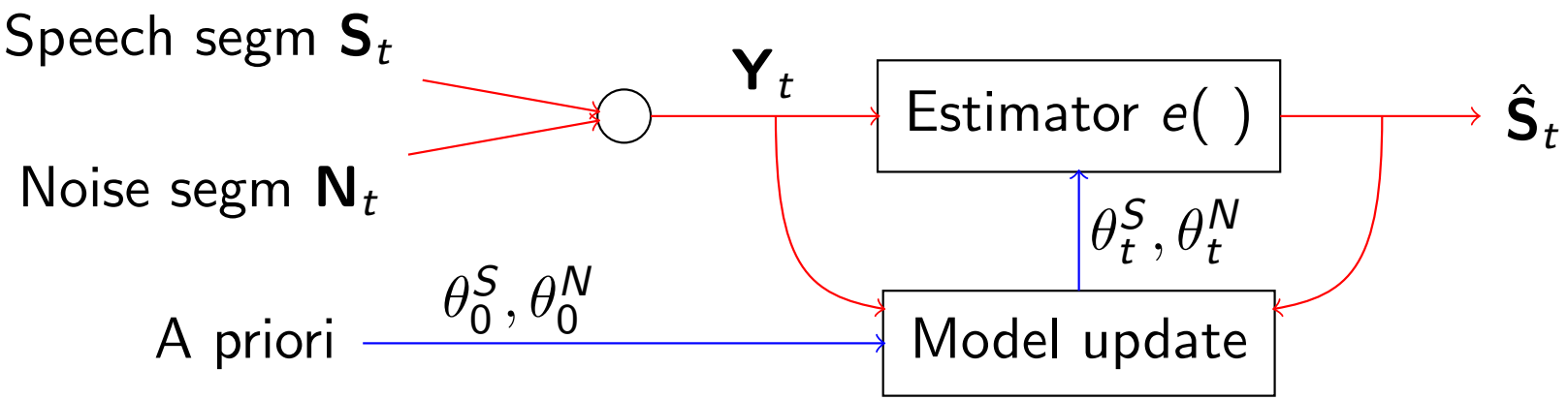
controlled by frequency-specific Bilateral Coherence

Fast Single-channel Noise Reduction



Ideally, $\hat{\mathbf{S}}_t = e(\mathbf{S}_t|\mathbf{Y}_t, \mathbf{Y}_{t-1}, \ldots, \mathbf{Y}_0)$

Fast Single-channel Noise Reduction



$$\hat{\mathbf{S}}_t = e(\mathbf{S}_t|\mathbf{Y}_t, \theta_t^S, \theta_t^N)$$

Fast Single-channel Noise Reduction

Models for Speech and Noise include

- Probability density functions
- Speech and Noise Spectra

and can also include prior knowledge of

- Spectral-shape correlations (frequency)
- Spectral modulation patterns (time)

Preliminary Performance Evaluation

MatLab algorithm implementations

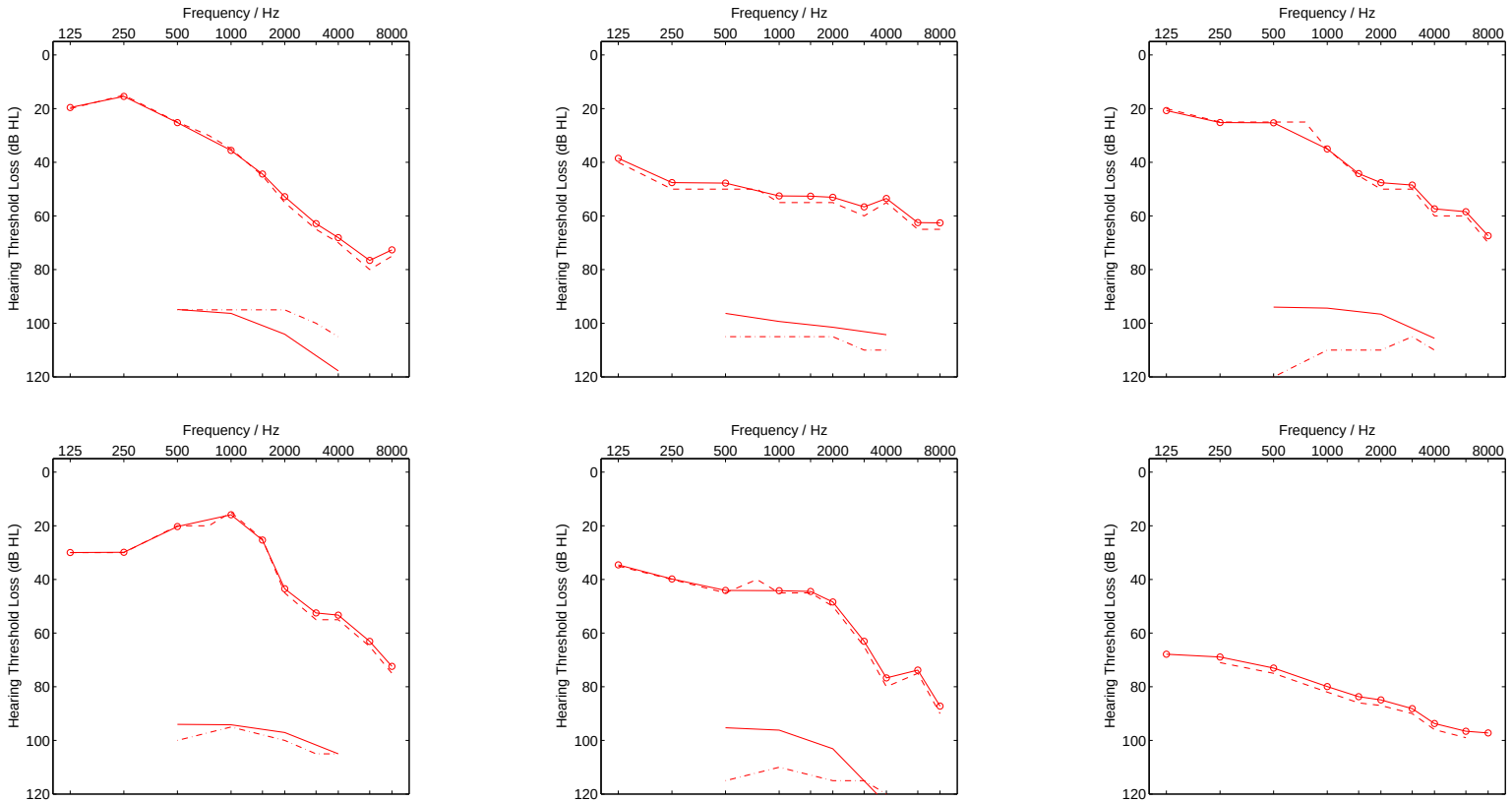
For Noise Suppression algorithms:

- Calculated performance, with model-simulated hearing losses:
- Segmental SII (*segSII*), (like Rhebergen et al., 2005, 2006)
- Signal-to-noise Loudness Level Difference (*SNLL*) (phon), (like Moore et al., 1997, 2004)

(Other measures for Feedback Suppression.)

Simulated Hearing Losses

Auditory Excitation-pattern Model



Test Conditions

Environment	**Desired**	**Azimuth**	**Competing**	**Azimuth**
Low-rev. room	Speech	0	Speech-shaped	60
Living-room	Speech	0	Music	60
Cafeteria	Speech	0	Cafeteria Noise	diffuse

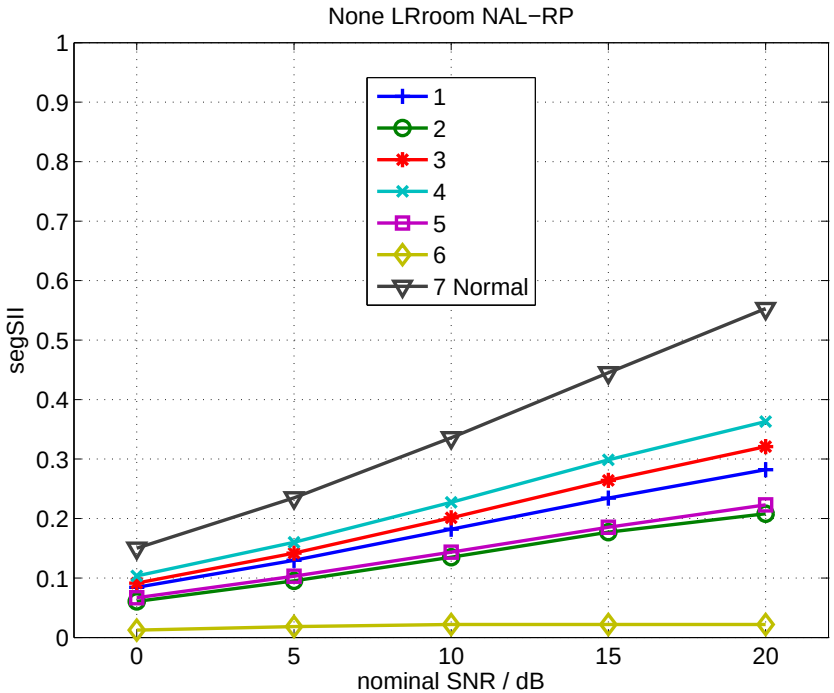
Fixed Speech Level: 70 dB SPL.

Speech/Noise ratios: $0 - 20$ dB.

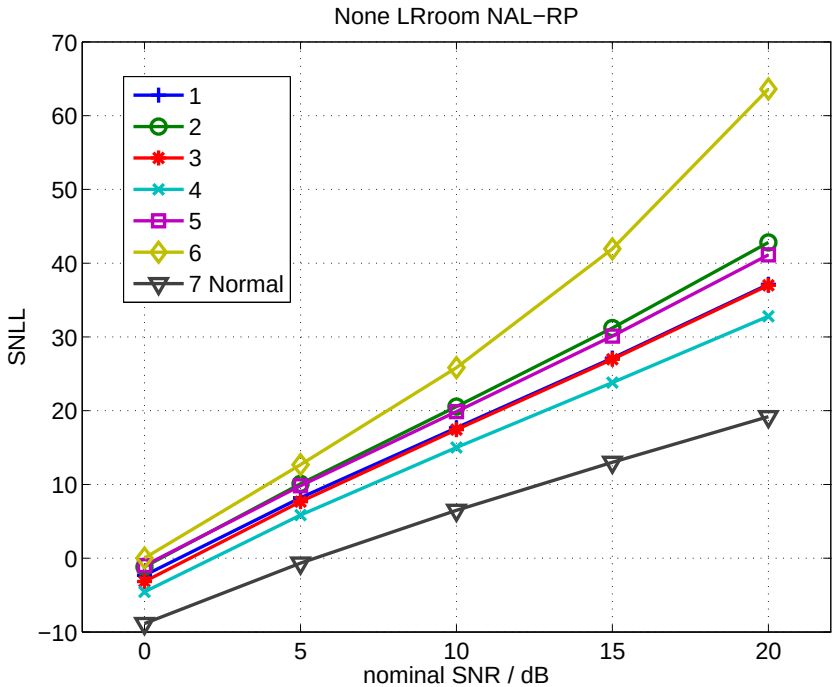
Baseline Result, no enhancement algorithms

Low-reverberant Room: Speech + Speech-shaped Noise 60 deg.

Speech Recognition



Speech/Noise Loudness



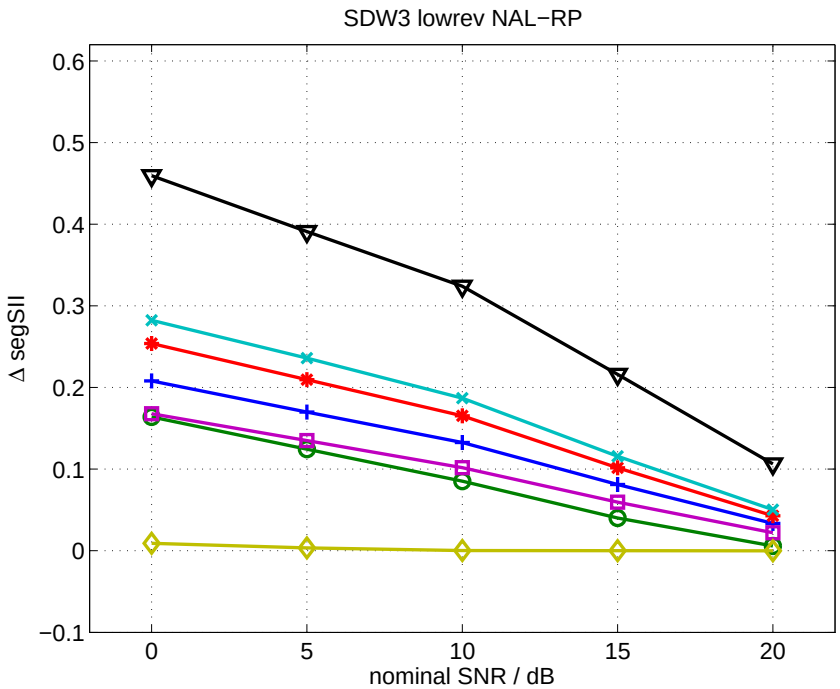
Algorithm effects shown as *deviations* from baseline.

Unilateral 3-microphone Beamforming

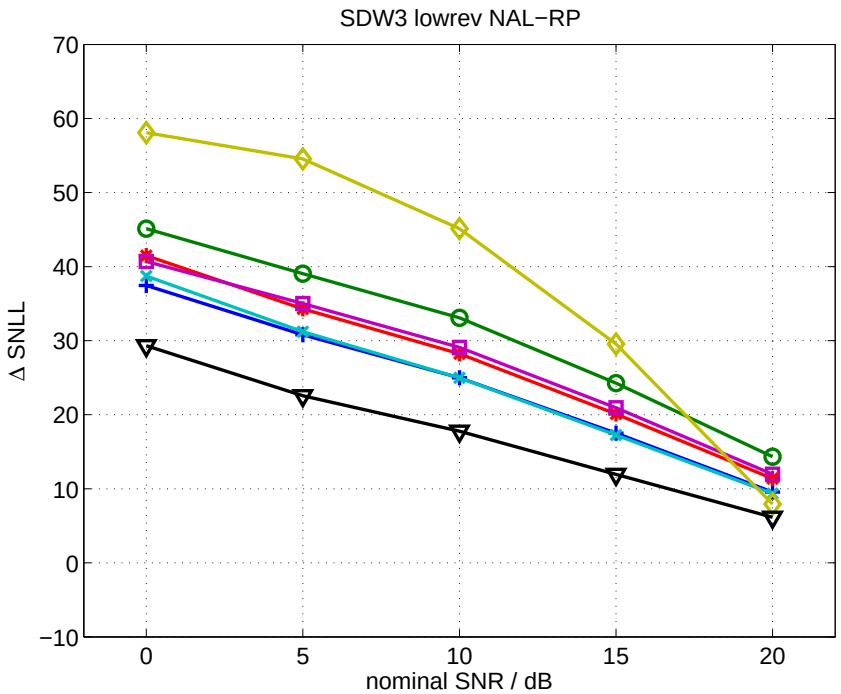
Low-reverberant Room: Speech + Speech-shaped Noise 60 deg.

Expected Improvement:

Speech Recognition



Speech/Noise Loudness

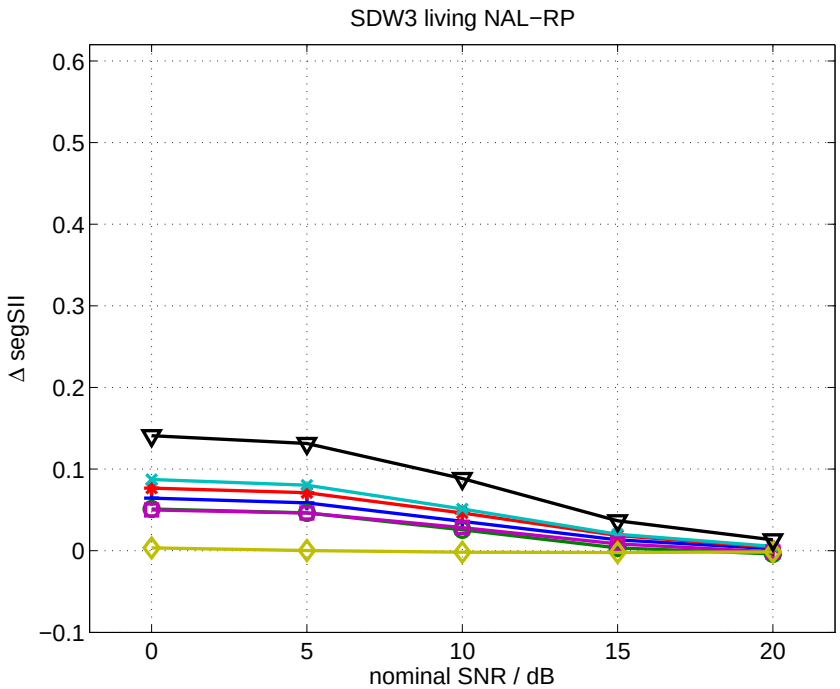


Unilateral 3-microphone Beamforming

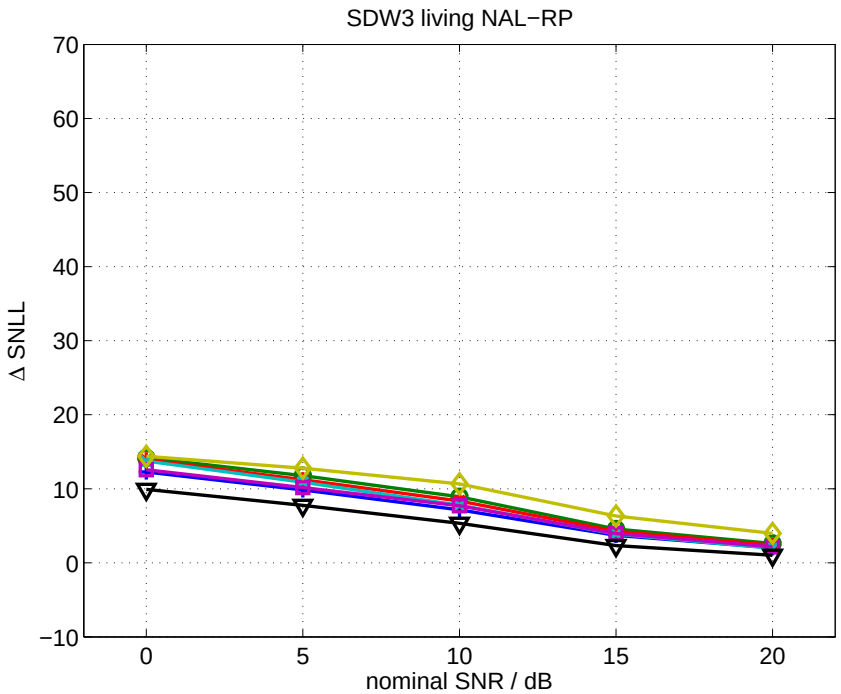
Living-Room: Speech + Music 60 deg.

Expected Improvement:

Speech Recognition



Speech/Noise Loudness

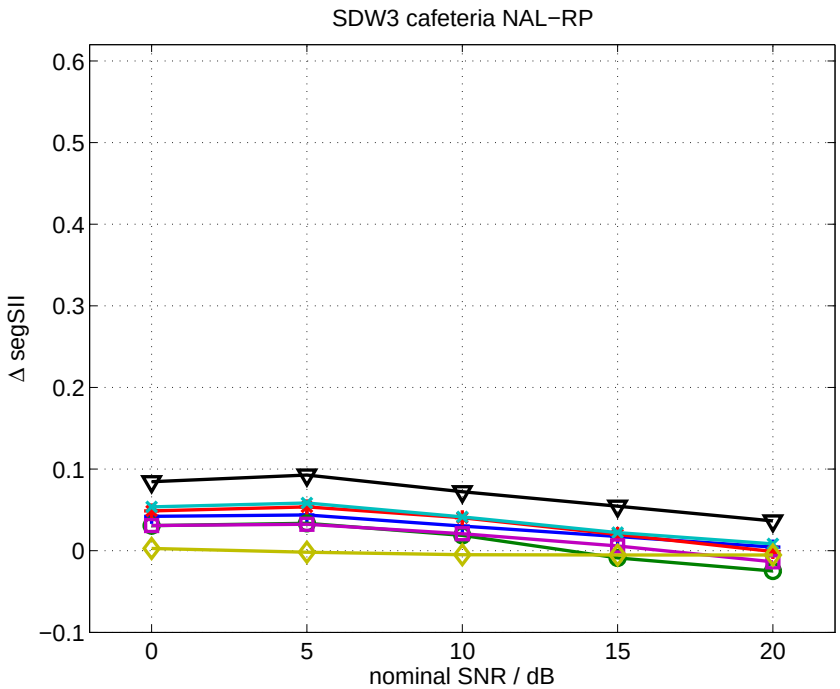


Unilateral 3-microphone Beamforming

Cafeteria: Speech + Babble.

Expected Improvement:

Speech Recognition



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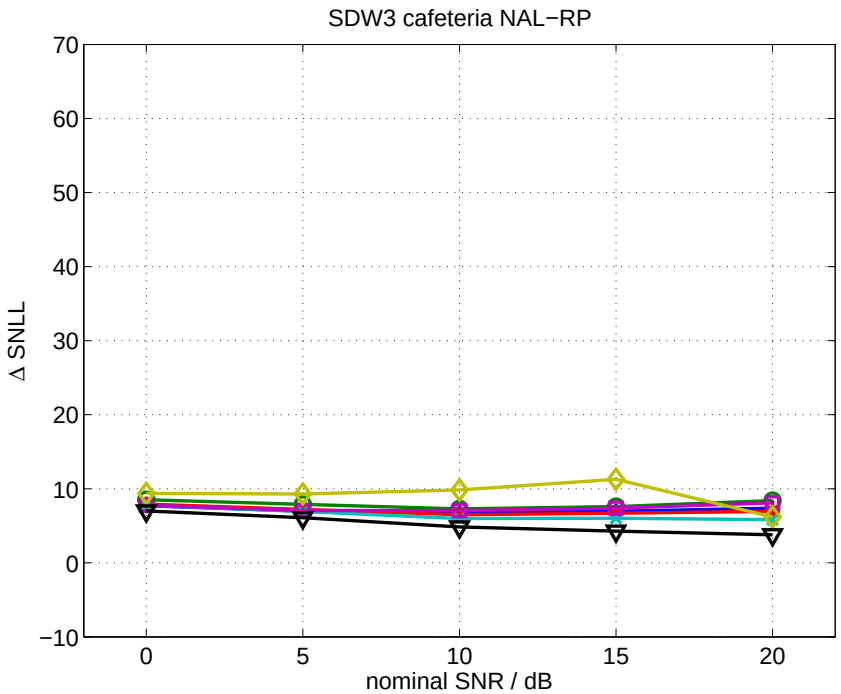

Bilateral Coherence Dereverberation/Noise Reduction

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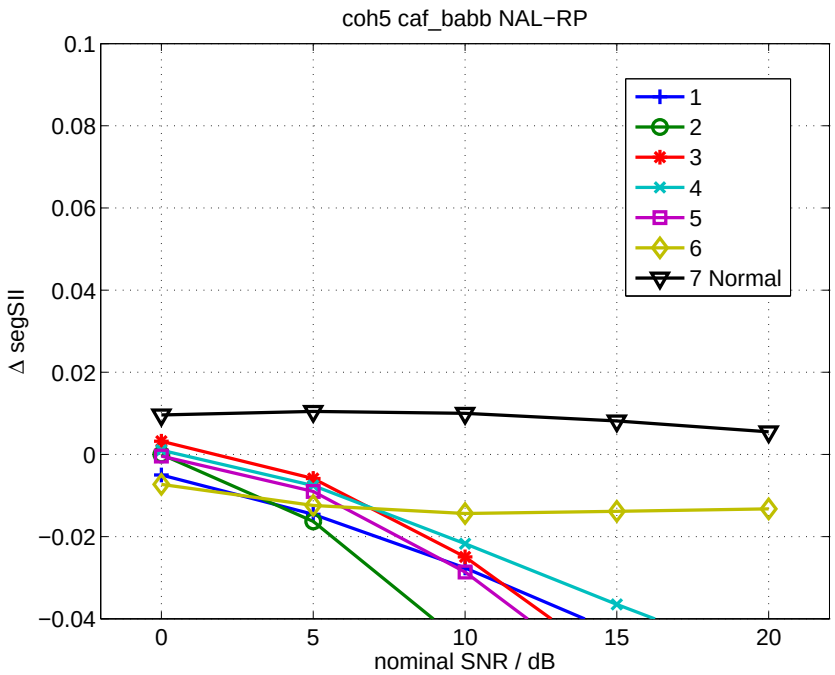
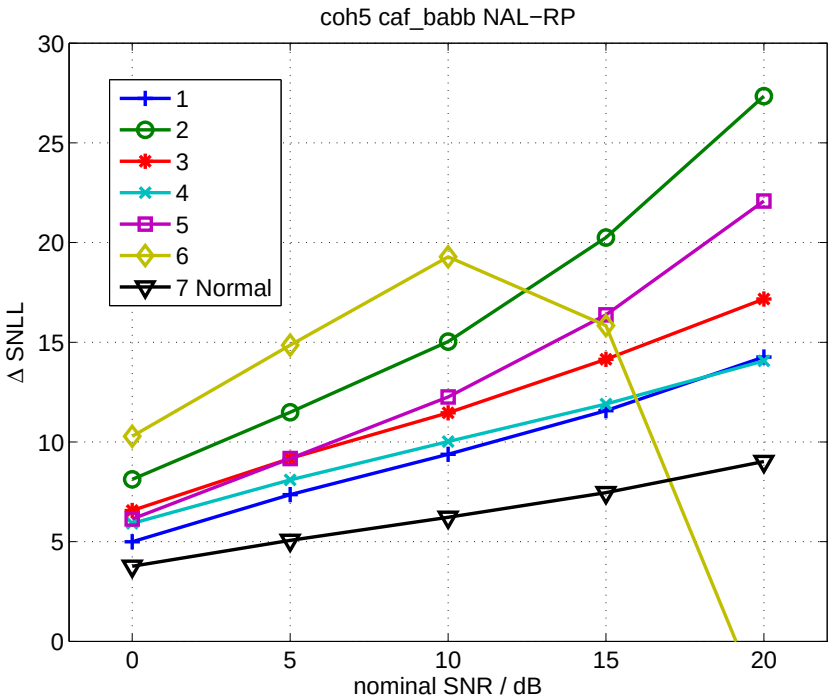


Speech/Noise Loudness



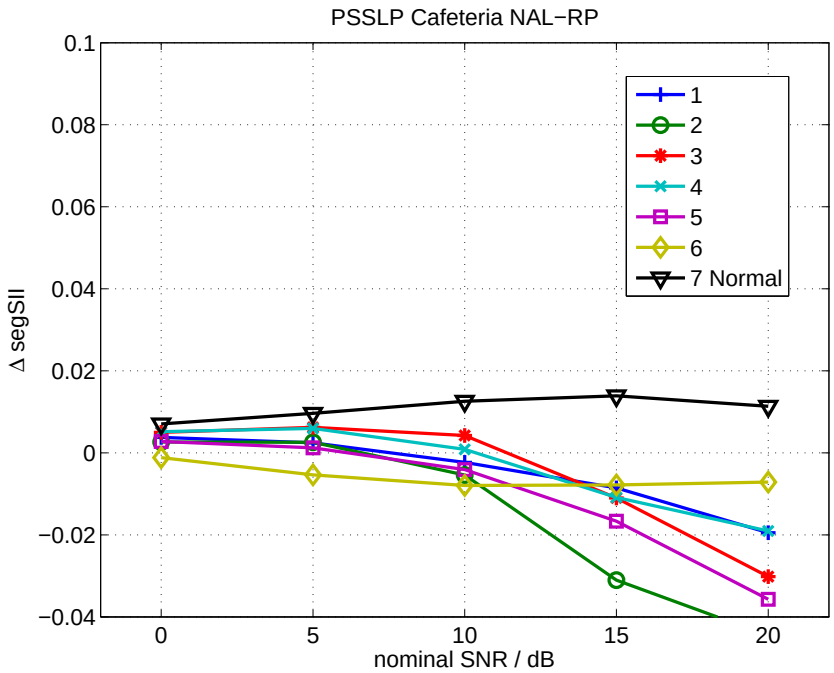
(Note extended scale)

Fast Single-channel Noise Reduction

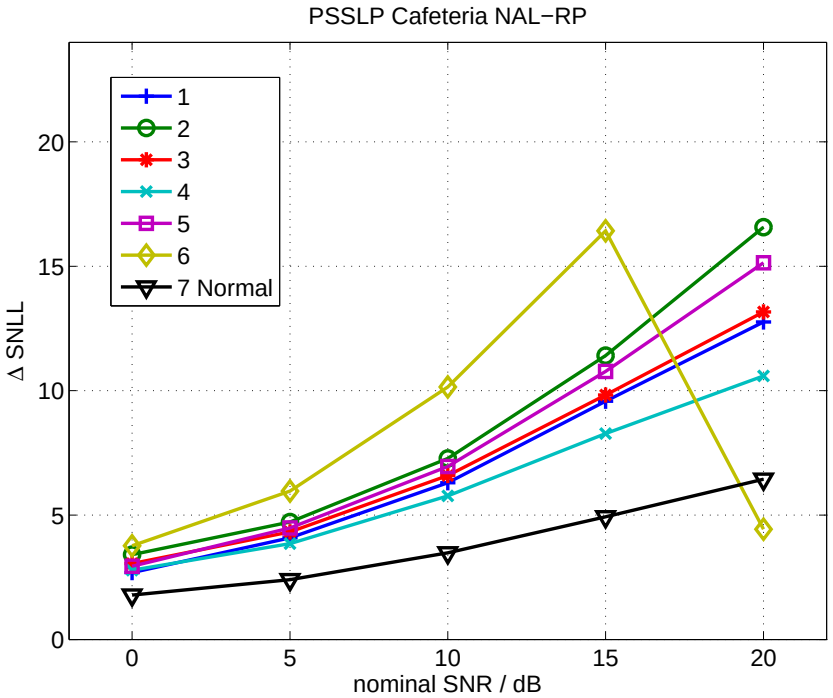
Cafeteria: Speech + Babble.

Expected Improvement:

Speech Recognition



Speech/Noise Loudness



(Note extended scale)

Noise Reduction Benefit

Preliminary Calculated Results with Model-simulated Hearing Losses

- Multi-microphone Beamforming:
  - Improves speech recognition in many environments
  - Improves Signal/Noise Loudness Ratio
  - More severe hearing loss $\rightarrow$
    - smaller intelligibility improvement at given SNR.
    - about equal SNR threshold improvement.

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  - Improves speech recognition in many environments
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  - More severe hearing loss $\rightarrow$
    - smaller intelligibility improvement at given SNR.
    - about equal SNR threshold improvement.
- Single-channel noise reduction:
  - Probably no improvement of speech recognition
  - Improves Signal/Noise Loudness Ratio