An Integrated Approach for Noise Reduction and Dynamic Range Compression in Hearing Aids

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Outline

- Introduction - hearing aids, hearing impairment
- Noise Reduction (NR)
- Dynamic Range Compression (DRC)
- Problem statement - Why integration is needed ?
- Integration of NR and DRC
- Results
- Conclusion

Introduction

Sensorineural hearing loss

- Threshold of hearing raised as a result of the hearing loss
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- multiple speakers, fans, traffic etc.
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Compensation of sensorineural hearing loss requires NR and DRC !

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Single-channel Noise Reduction

- Limited benefit with single-channel
- Exploits only spectral and temporal differences

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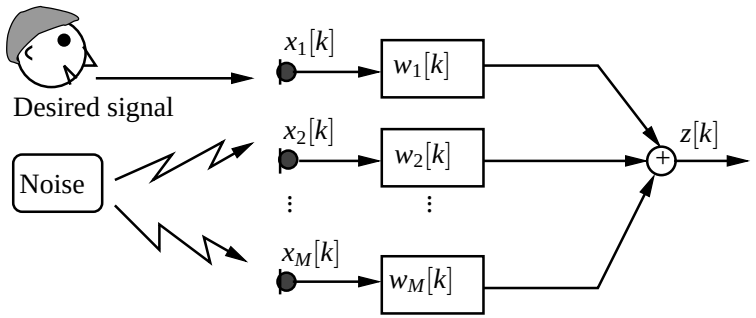
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Multichannel Noise Reduction

- Exploits spatial diversity of speech and noise
- GSC, Beamformer, MWF etc.



$$z[k] = \sum_{l=1}^{M} \mathbf{w}_l^T[k]\mathbf{x}_l[k] = \mathbf{w}^T[k]\mathbf{x}[k]$$

Dynamic Range Compression

Map the wide dynamic range of speech
into the reduced dynamic range of a hearing aid user !

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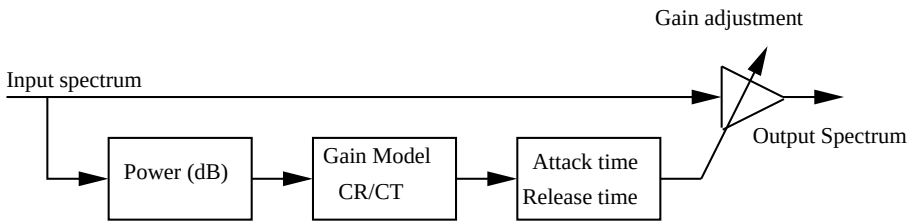
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- Weak sounds audible - loud sounds not uncomfortably loud

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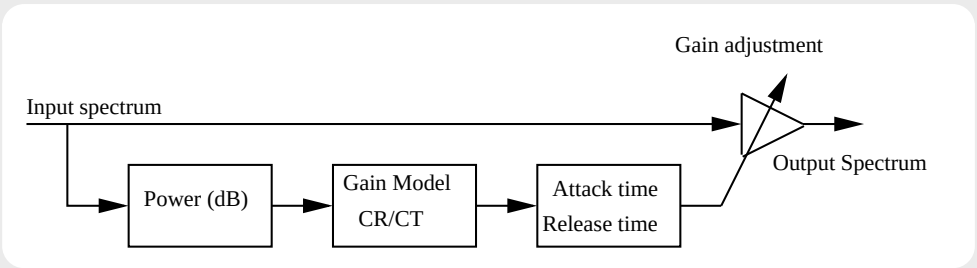
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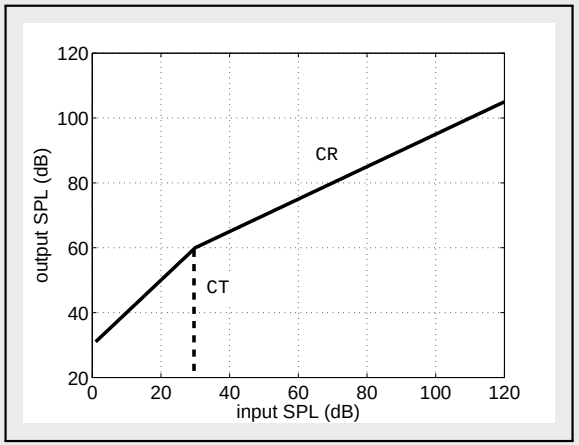


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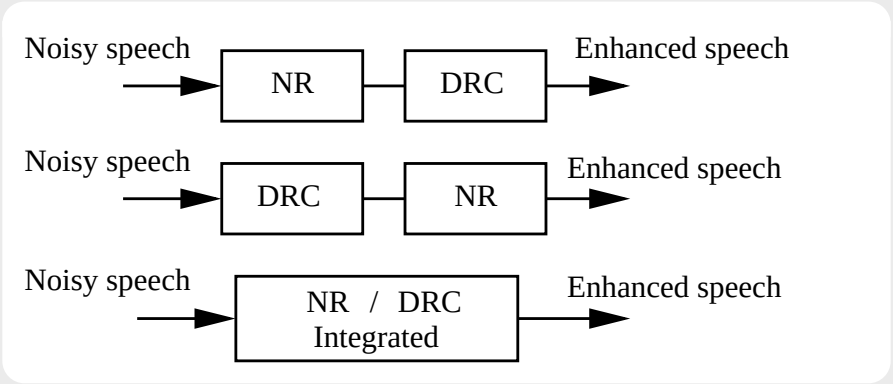
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- SNR improvement vs. Audibility vs. speech distortion

Problem statement

Existing mehtod

- Hearing aids typically use a serial concatenation
- Negatively affects the NR stage
- Residual noise after NR is amplified by the DRC
- Counteract and limit functionality of other algorithms



Integration of NR and DRC

Dual-Dynamic Range Compression

- Using switchable compression characteristic
- $P^{s}_{DRC,dB}$ - speech DRC (speech dominant case)
- $P^{n}_{DRC,dB}$ - noise DRC (noise dominant case)

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β reflects the amount of speech/noise contribution in each segment

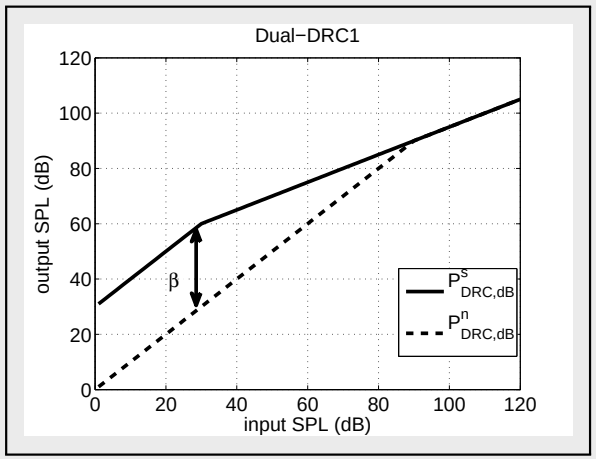
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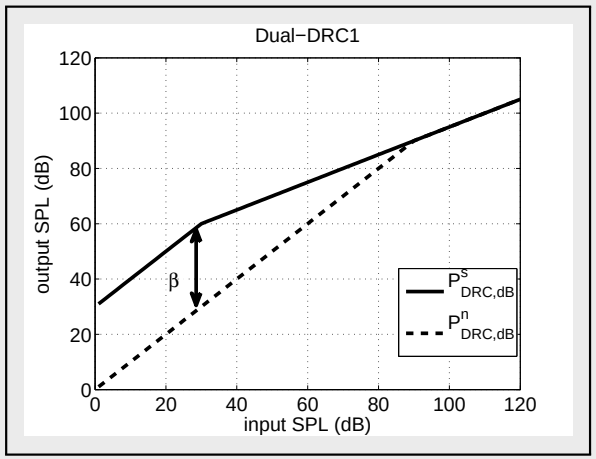
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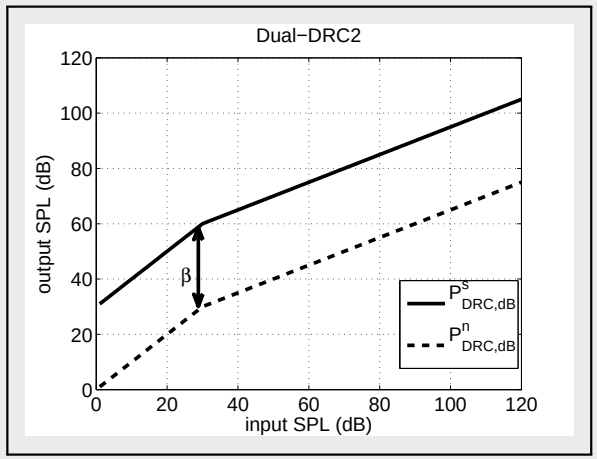
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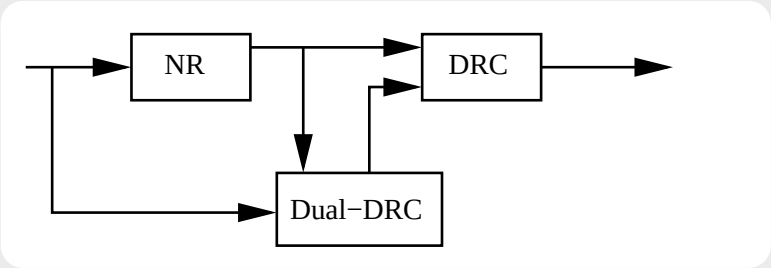
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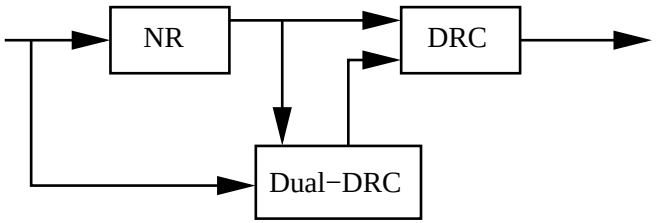
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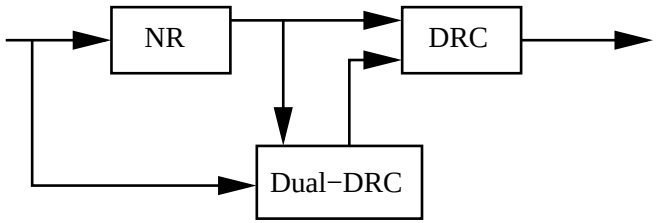


$$\alpha_{NR}(\omega, k) = \frac{P^s_{out,NR}(\omega, k) + P^n_{out,NR}(\omega, k)}{P^s_{in,NR}(\omega, k) + P^n_{in,NR}(\omega, k)}$$

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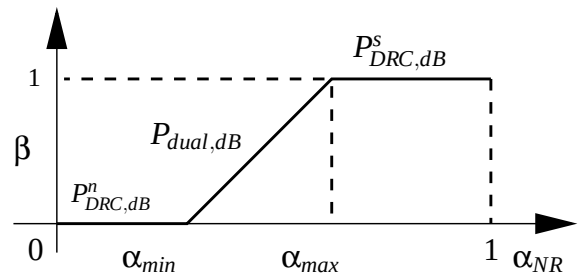
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- Threshold function (speech/noise contribution)

$$\beta = \begin{cases} \beta = 1 & if\ \alpha_{NR} \geq \alpha_{max} \\ \beta = 0 & if\ \alpha_{NR} \leq \alpha_{min} \\ \beta = \frac{\alpha_{NR}-\alpha_{min}}{\alpha_{max}-\alpha_{min}} & otherwise \end{cases}$$



Results

Experimental Set-up

- Multi-microphone NR used is the well known GSC
- 2-microphone behind-the-ear hearing aid
- speech and the noise sources are located at 0° and 120°
- Multi-talker babble noise at 0dB input SNR
- Input level 65dB at the hearing aid microphones
- fast-acting DRC with a gain of 30dB

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Objective Quality Measures

- Intelligibility-weighted signal-to-noise ratio
- Frequency-weighted log-spectral signal distortion

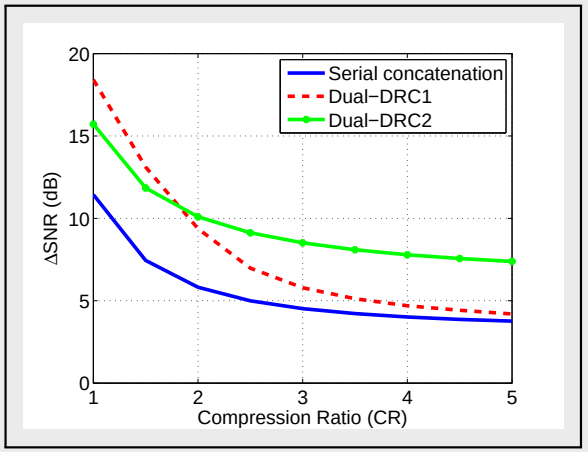
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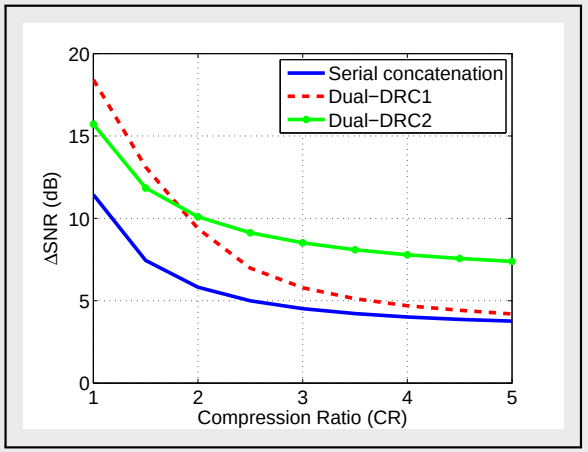
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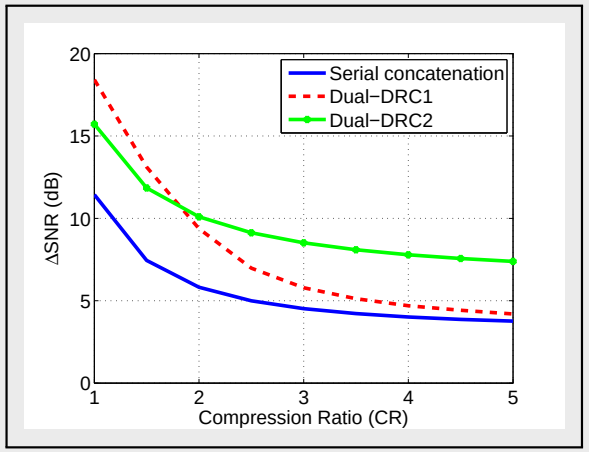


Experiment 2 (Effect of CR on SD)

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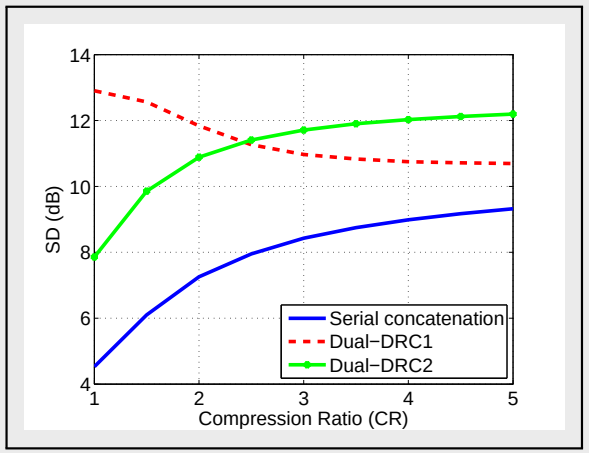
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Experiment 2 (Effect of CR on SD)

- SD increase as CR increases
- SD for dual-DRC2 can be controlled
- SD decreases for dual-DRC1
- Low impact of β at high CR



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- Dual-DRC resulted in an SNR improvement compared to a serial concatenation of NR and DRC