INTERNATIONAL AUDIO LABORATORIES ERLANGEN
A joint institution of Fraunhofer IIS and Universität Erlangen-Nürnberg

Direction Preserving Wind Noise Reduction of B-Format Signals

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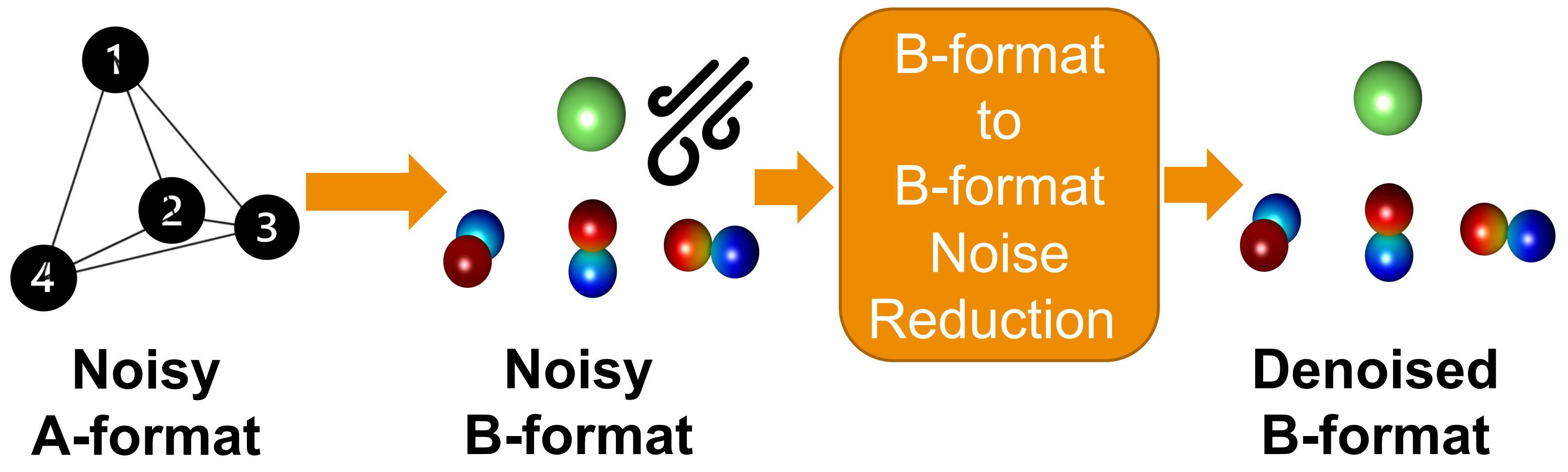
1. Introduction

- Soundfield microphones can be used to capture 3D audio via first-order Ambisonics (B-format)
- Wind noise in outdoor recordings degrades the sound quality and speech intelligibility

Tasks:

- Enhance desired signal and reduce wind noise
- Preserve spatial distribution of all sound-field components

2. Problem Formulation



Signal model $\mathbf{x}_B = \underbrace{S\,\mathbf{b}(\Omega)}_{\text{Desired}} + \underbrace{\mathbf{v}_B}_{\text{Undesired}}$

S	Speech source
$\mathbf{b}(\Omega)$	Plane-wave steering vector
$\mathbf{v}_B$	Wind noise in B-format

Matrix spatial filtering $\mathbf{z}_B = \mathbf{W}\mathbf{x}_B$

$\mathbf{z}_B$	Enhanced B-format signal
$\mathbf{W}$	Filter matrix

Existing methods based on Parametric Multichannel Wiener Filter (PMWF)

- Beamform and project (BP) method [1,3]
- BP with partial mixing (BP+PM) [2]
- Direction-preserving (DP) method [3]

3. Proposed Method

Motivation

- PMWF: tradeoff parameter μ controls desired-signal distortion and noise reduction
- [3]: Ambisonic-to-Ambisonic noise reduction methods using fixed μ
- [4]: Wind noise reduction using signal-dependent μ based on difference-to-sum power ratio

Present Work

- Derive **dipole-to-omnidirectional power ratio (PR)**
- Use PR for B-format to B-format wind noise reduction

$$\boxed{\mathrm{PR} = \frac{g_o^2}{g_d^2}\frac{\phi_{\mathrm{dip}}}{\phi_{\mathrm{omni}}}}$$

g_o, g_d	omnidirectional and dipole gains from B-format encoding
ϕ_{omni}	omnidirectional power
ϕ_{dip}	dipole power

- Plane waves: $\boxed{\mathrm{PR} = 1}$ Wind noise: $\boxed{\mathrm{PR} = 9}$
- "Windiness“ $\widetilde{\mathrm{PR}} = \min\{\max\{(\mathrm{PR} - 1)/8, 0\}, 1\}$
- Proposed trade-off parameter $\boxed{\mu = 1 + \rho\,\widetilde{\mathrm{PR}}}$

Adjustable scaling parameter

References

[1] C. Borrelli, A. Canclini, F. Antonacci, A. Sarti, and S. Tubaro, “A denoising methodology for higher order ambisonics recordings,” in *Proc. Intl. Workshop Acoust. Signal Enhancement (IWAENC)*, Tokyo, Japan, Sept. 2018.

[2] T. J. Klasen, T. V. den Bogaert, M. Moonen, and J. Wouters, “Binaural noise reduction algorithms for hearing aids that preserve interaural time delay cues,” *IEEE Trans. Signal Process.*, vol. 55, no. 4, pp. 1579–1585, 2007.

[3] A. Herzog and E. A. P. Habets, “Direction-preserving Wiener matrix filtering for Ambisonic input-output systems,” in *Proc. IEEE Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP)*, Brighton, UK, May 2019.

[4] D. Mirabilii and E. A.P. Habets, “Multi-channel wind noise reduction using the Corcos model,” in *Proc. IEEE Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP)*, Brighton, UK, May 2019.

4. Performance Evaluation

Simulation Setup

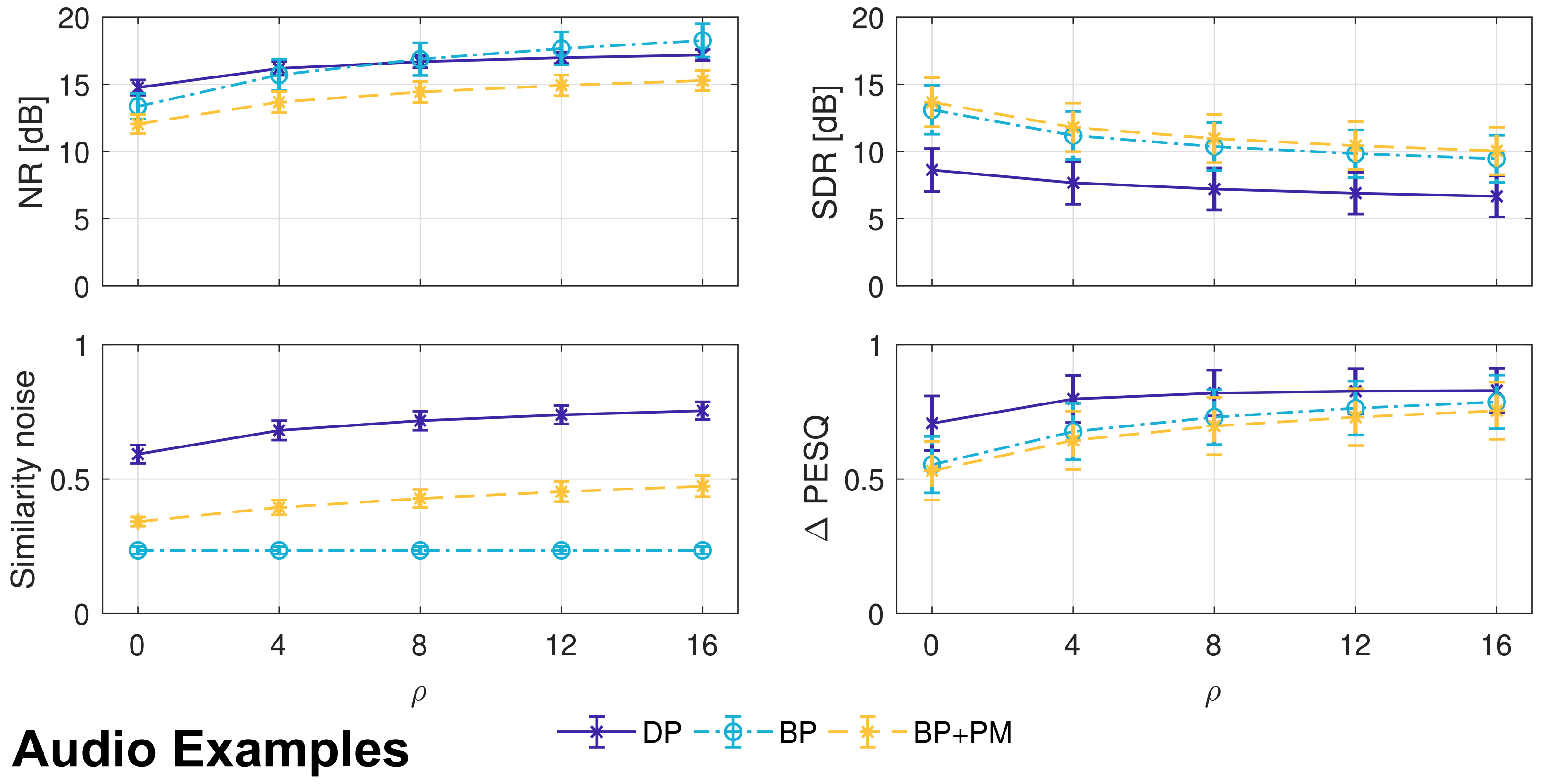
- 10 wind noise recordings with AMBEO VR mic
- 2 different english speech files (plane-wave encoding)
- 4 different speech directions (DOAs), 0 dB SNR

Processing

- Short-time Fourier transform domain processing
- Recursive estimation of signal statistics, oracle DOA
- Max. noise reduction: 20 dB

Performance Measures

- Noise reduction (NR), signal-to-distortion ratio (SDR)
- spatial preservation of noise (similarity noise)
- PESQ improvement (ΔPESQ)



Audio Examples
https://www.audiolabs-erlangen.de/resources/2021-ICASSP-BWNR

5. Conclusions

- NR, similarity noise and ΔPESQ increase with ρ
- **BP:** + NR and SDR, - similarity noise and ΔPESQ
- **BP+PM:** + SDR, + similarity noise, - NR and ΔPESQ
- **DP:** + NR, similarity noise and ΔPESQ, - SDR