Subjective Evaluation of binaural noise reduction and cue preservation algorithms in a cocktail party scenario

Daniel Marquardt, Ivo Merks, Tao Zhang, Simon Doclo
Starkey Hearing Technologies, University of Oldenburg

INTRODUCTION

- Improve speech intelligibility in binaural hearing aids using binaural beamforming algorithms
- Subjectively compare several binaural algorithms with different design criteria in terms of interference and noise reduction and binaural cue preservation for a cocktail party scenario

Speech intelligibility:

- 50% SRT measured using Oldenburg Sentence Test (OLSA) with time-compressed speech (compressed to 40%) [1]

Subjective Preference Test:

- Rank test with spatial scenario (desired + interfering speaker) projected on a screen to provide visual information
- Task: Rate overall preference when listening to the OLSA speaker

ALGORITHMS / IMPLEMENTATION

Reference algorithm:

- Bilateral MVDR beamformer (SNR optimal) steered towards 0° (**BIL**)

Binaural algorithms [2]:

- Binaural **MVDR** (SNR optimal) and binaural **MPDR** (SINR optimal) only preserving binaural cues of target source

Constrained binaural algorithms [2]:

- Binaural **LCMV** (SNR optimal) and binaural **LCMP** (SINR optimal) also preserving binaural cues of residual interfering source

Algorithms require several quantities to be estimated from the signals:

	Target DOA	Interference DOA	Signal correlation matrix	Diffuse coherence matrix
BIL				Required
MVDR	Required			Required
MPDR	Required		Required	
LCMV	Required	Required		Required
LCMP	Required	Required	Required	

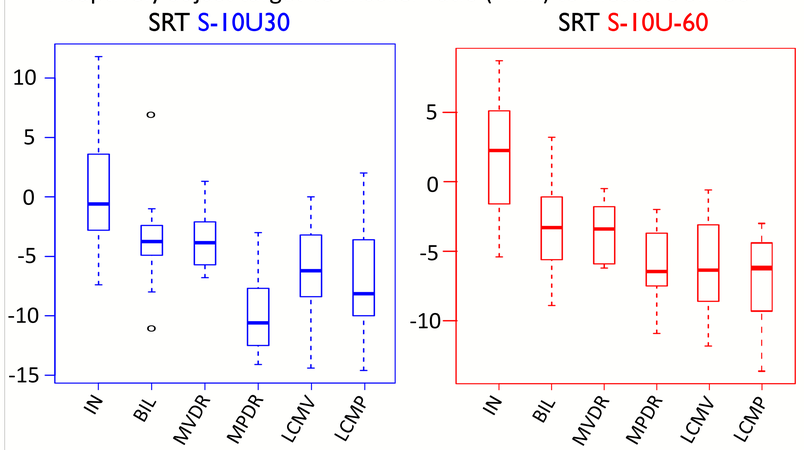
- DOAs estimated using SVM-based method [3], steering vectors and diffuse coherence matrix calculated from anechoic prototype ATFs.
- Weighted-overlap-add, f_s=16kHz, 10ms block length, 50% overlap

Acoustic Scenario:

- Desired source (German speaker) at -10°,interfering source (English speaker) at 30° (**S-10U30**) or -60° (**S-10U-60**), diffuse babble noise (SNR: -2dB)

SPEECH INTELLIGBILITY RESULTS

- N=14 self-reported normal hearing subjects
- Adaptively adjust target-to-masker-ratio (TMR) to measure SRT50



	IN		BIL		MVDR		MPDR		LCMV		LCMP	
IN			*	***	*	***	***	***	***	***	***	***
BIL	*	***			o	o	***	***	o	***	*	***
MVDR	*	***	o	o			***	**	o	*	**	**
MPDR	***	***	***	***	***	**			**	o	*	o
LCMV	***	***	o	***	o	*	**	o			o	o
LCMP	***	***	*	***	**	**	*	o	o	o		

Significance of SRT differences for **S-10U30** and **S-10U-60**

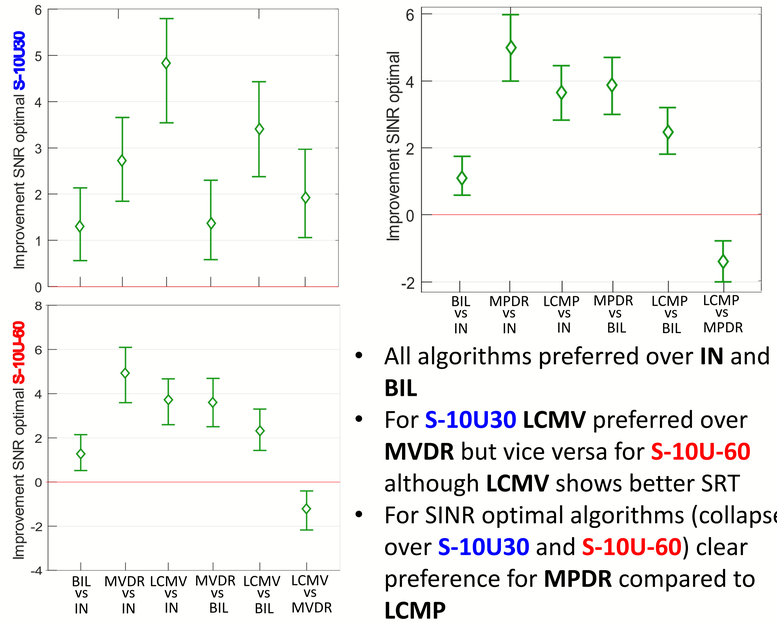
- All considered algorithms significantly improve speech intelligibility
- Binaural **MVDR** does not improve SRT compared to bilateral **BIL** despite better SNR improvement but distortions of interference cues
- **LCMV** outperforms **BIL** and **MVDR** due to additional binaural cue preservation and better suppression of interfering source [2] (only significant for **S-10U-60**)
- **MPDR** clearly outperforms other algorithms for **S-10U30** and **LCMP** shows no improvement over **MPDR**

REFERENCES

[1] A. Schlueter, T. Brand, U. Lemke, S. Nitzschner, B. Kollmeier, and I. Holube, "Speech perception at positive signal-to-noise ratios using adaptive adjustment of time compression," The Journal of the Acoustical Society of America, vol. 138, no. 5, pp. 3320–3331, 2015.
[2] E. Hadad, D. Marquardt, S. Doclo, and S. Gannot, "Theoretical Analysis of Binaural Transfer Function MVDR Beamformers with Interference Cue Preservation Constraints," IEEE/ACM Trans. Audio, Speech and Lang. Proc., vol. 23, no. 12, pp. 2449–2464, Dec. 2015.
[3] H. Kayser and J. Anemüller, "A discriminative learning approach to probabilistic acoustic source localization," in Proc. International Workshop on Acoustic Signal Enhancement (IWAENC), Juan-les-Pins, France, Sep. 2014, pp. 99–103.
[4] K. Wojcicki, K. Fitz, K. Recker, D. Reynolds, and T. Zhang, "Sidechain harmonic enhancement of noise corrupted speech for hearing impaired listeners," in Proc. IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA), Oct 2015, pp. 1–5.

PREFERENCE TEST RESULTS

- Same **S-10U30** and **S-10U-60** scenarios as for SRT measurements (no time-compressed speech) and TMR of -10 and 0 dB, 4 algorithms compared per experiment in a rank test
- N=9 self-reported normal hearing subjects
- Lack of overlap with zero line indicates significant result [4]



- All algorithms preferred over **IN** and **BIL**
- For **S-10U30** **LCMV** preferred over **MVDR** but vice versa for **S-10U-60** although **LCMV** shows better SRT
- For SINR optimal algorithms (collapsed over **S-10U30** and **S-10U-60**) clear preference for **MPDR** compared to **LCMP**

SUMMARY

- Binaural algorithms significantly improve speech intelligibility in cocktail party scenarios and are preferred over bilateral algorithms
- SNR optimal algorithms: **LCMV** improves SRT compared to **MVDR** (significant for **S-10U-60**) and is subjectively preferred for **S-10U30**
- SINR optimal algorithms: **LCMP** does not improve intelligibility or preference over **MPDR** for both spatial scenarios

This work was supported by the Cluster of Excellence 1077 Hearing4all, funded by the German Research Foundation (DFG), and a research gift from Starkey Hearing Technologies.