Robust FIR Filters for Wireless Low-Frequency Sound Zones

Mo Zhou* Martin Bo Møller† Christian Sejer Pedersen* Jan Østergaard*

*Aalborg University, Aalborg, Denmark †Bang & Olufsen, Struer, Denmark
{moz,cp,jo}@es.aau.dk, mim@bang-olufsen.dk

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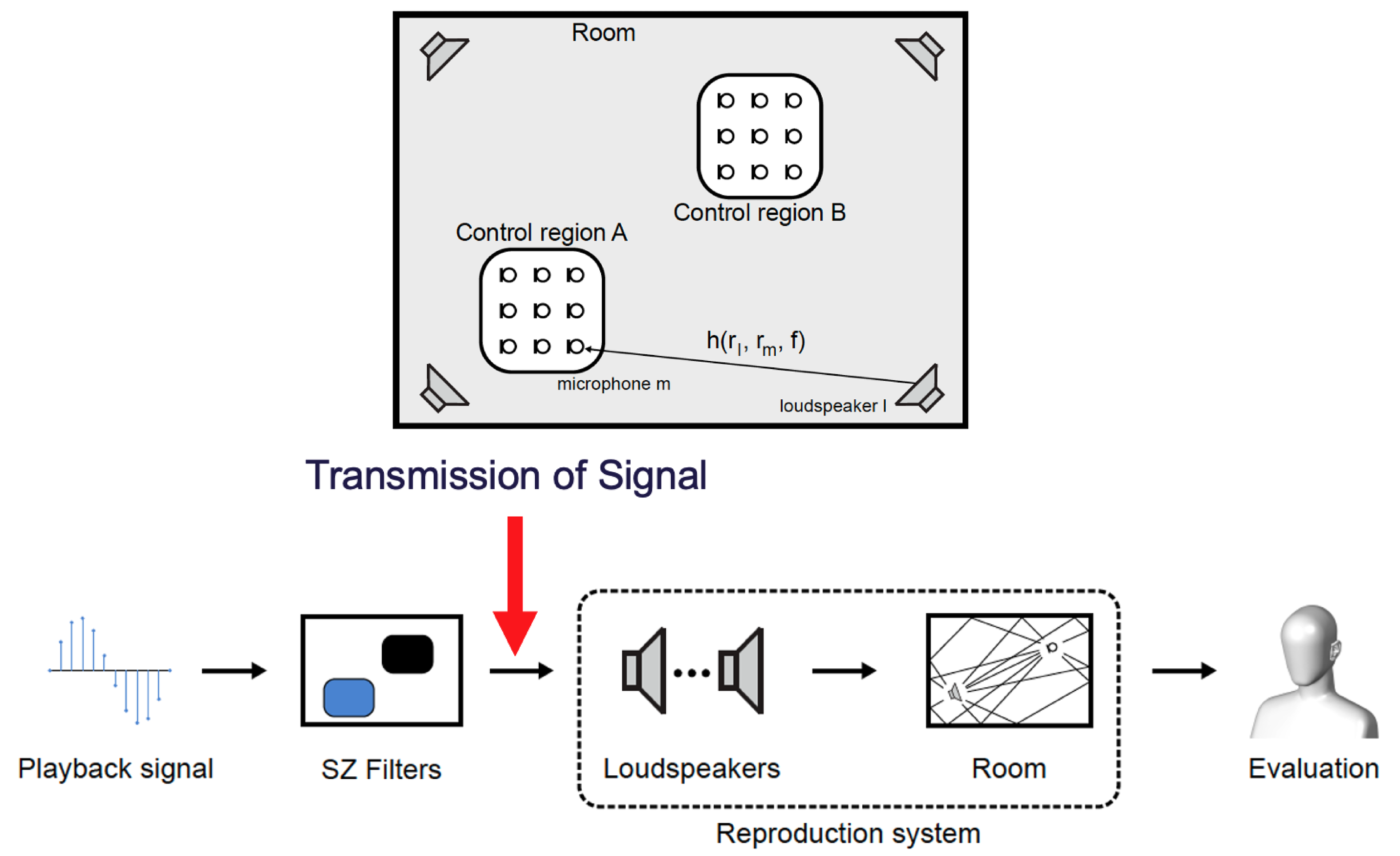
Wireless Low-Frequency Sound Zones

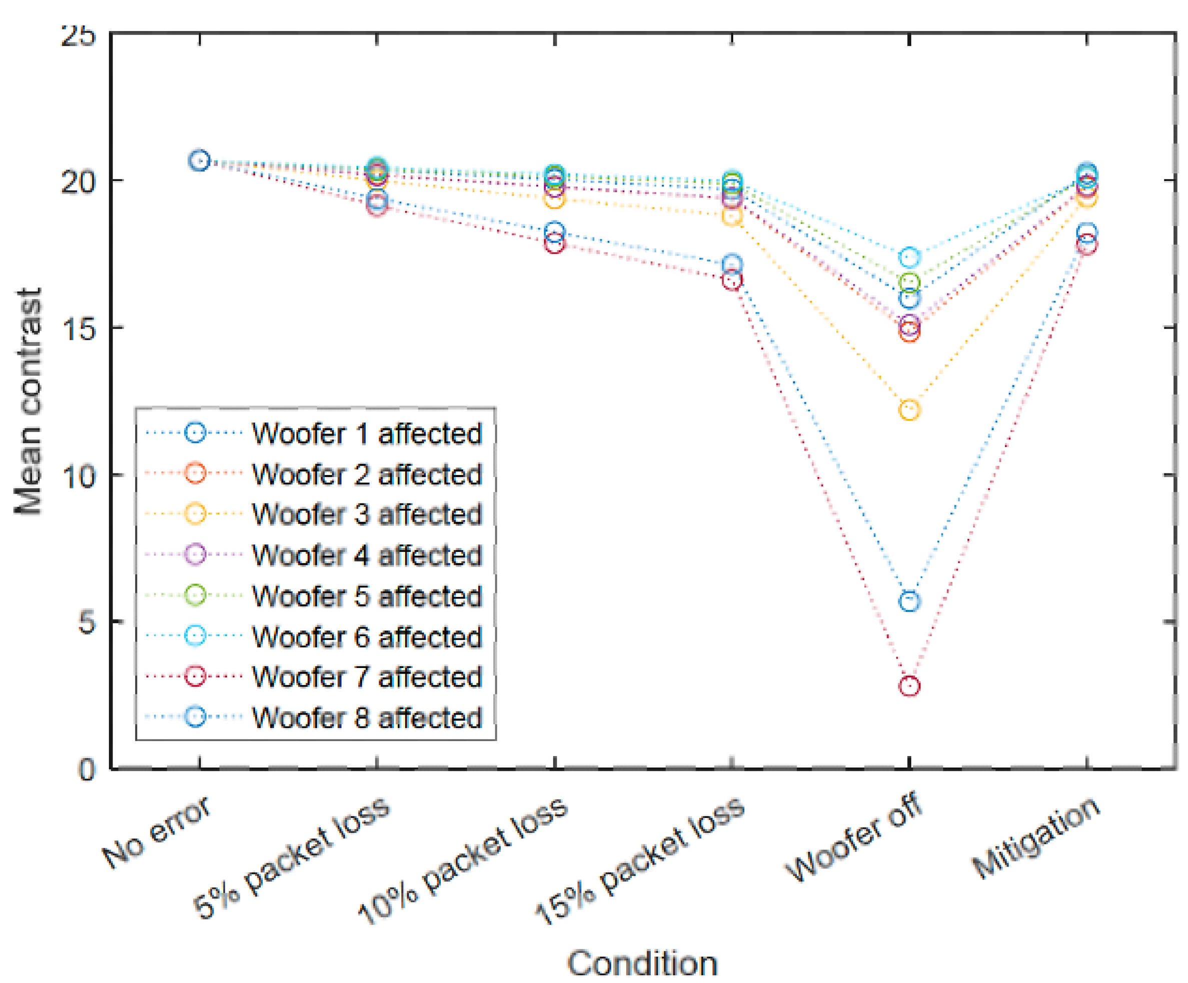
- Low-frequency sound zones system:



- Cable: high speed, robustness
- **Wireless**:
  - portability, increased flexibility, lower installation costs
  - **bit errors and loss of packets**

Effect of Packet Loss

- Lower contrast and audio quality
- More leakage in the dark zone



Robust FIR Filters Estimation

- Assume independent packet loss in each channel l and spectrally flat source signal, we minimize the following cost function with respect to the expected packet losses,

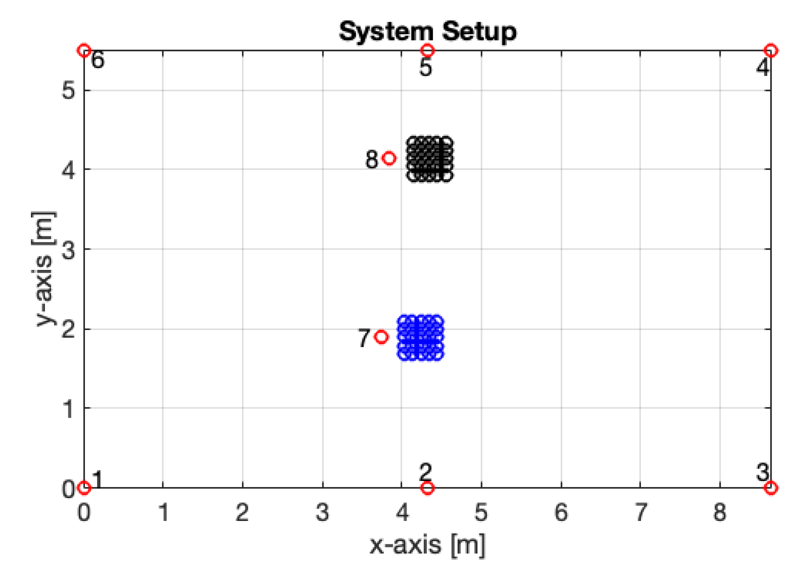
$$J_{pl}(\boldsymbol{w}) = (1-\beta)\mathbb{E}\{\|\boldsymbol{p}_B - \boldsymbol{p}_T\|_2^2\} + \beta\mathbb{E}\{\|\boldsymbol{p}_D\|_2^2\} + \lambda_w \boldsymbol{w}^T \boldsymbol{R}_w \boldsymbol{w},$$

  where $\boldsymbol{p}_B, \boldsymbol{p}_D$ are the sound pressures in the bright and dark zones, $\boldsymbol{p}_T$ is the target sound pressure in the bright zone, $\boldsymbol{R}_w$ is a weighting matrix for controlling the filters' shape.
- The FIR filters can be estimated by

$$\boldsymbol{w}_{opt} = [(1-\beta)\boldsymbol{H}_B^T\boldsymbol{H}_B \odot \Omega + \beta\boldsymbol{H}_D^T\boldsymbol{H}_D \odot \Omega + \lambda_w\boldsymbol{R}_w]^{-1}(1-\beta)(\Psi \otimes \boldsymbol{I}_l)\boldsymbol{H}_B^T\boldsymbol{p}_T.$$

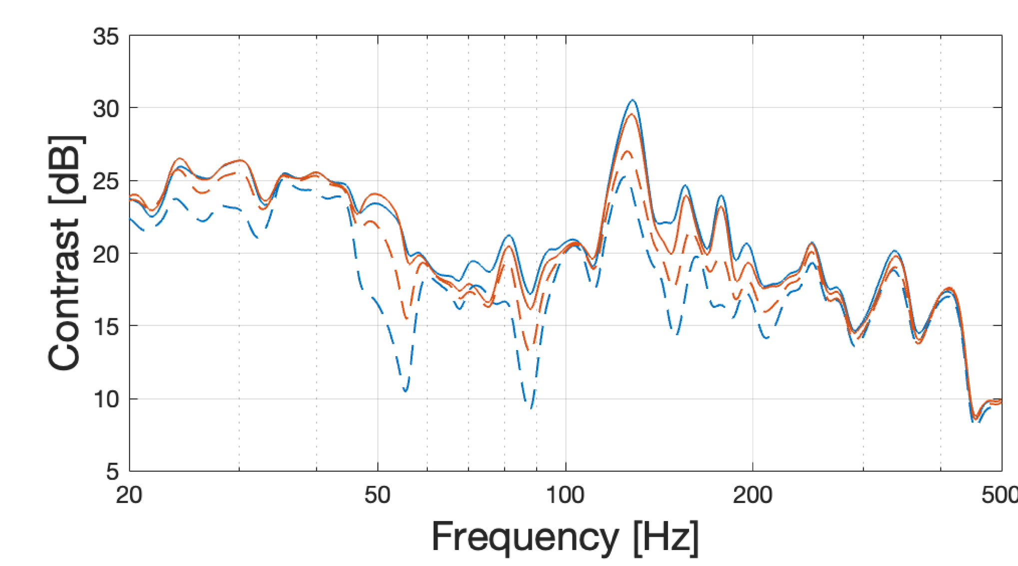
Performance

- Experiments on a simulated **5.5 m by 8.65 m by 2.7 m room** using Green's function for point sources in rectangular rooms, with **0.6s T60 reverberation time** and **8 loudspeakers** showed that our proposed filter is **robust to packet losses**.



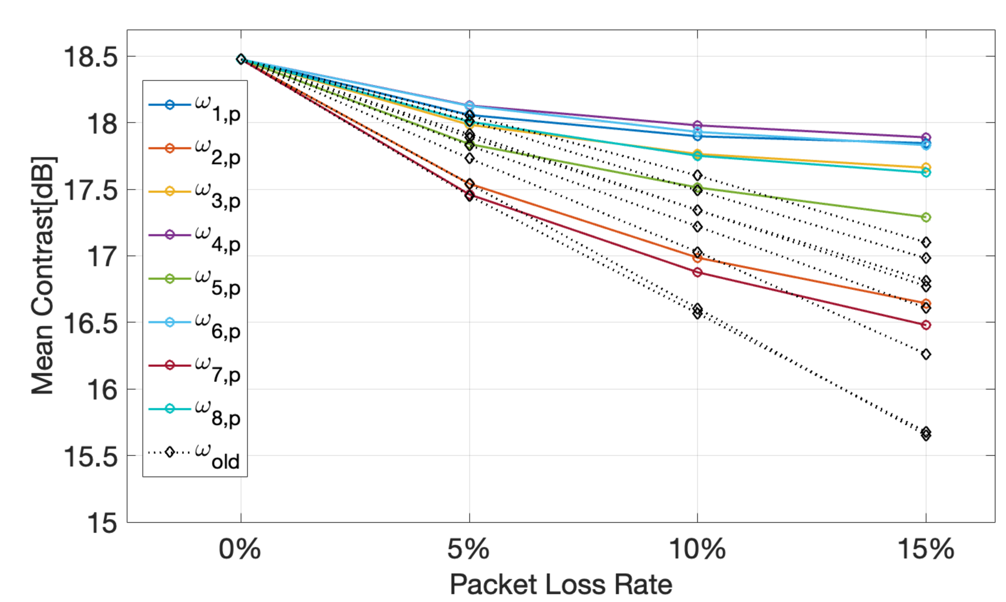
○ 75 microphones in the bright zone, ○ 75 microphones in the dark zone, ○ 8 loudspeakers.

- **Contrasts v.s. frequencies** of old and proposed filters when evaluated without packet loss, and with 10% packet loss in Channel 5.



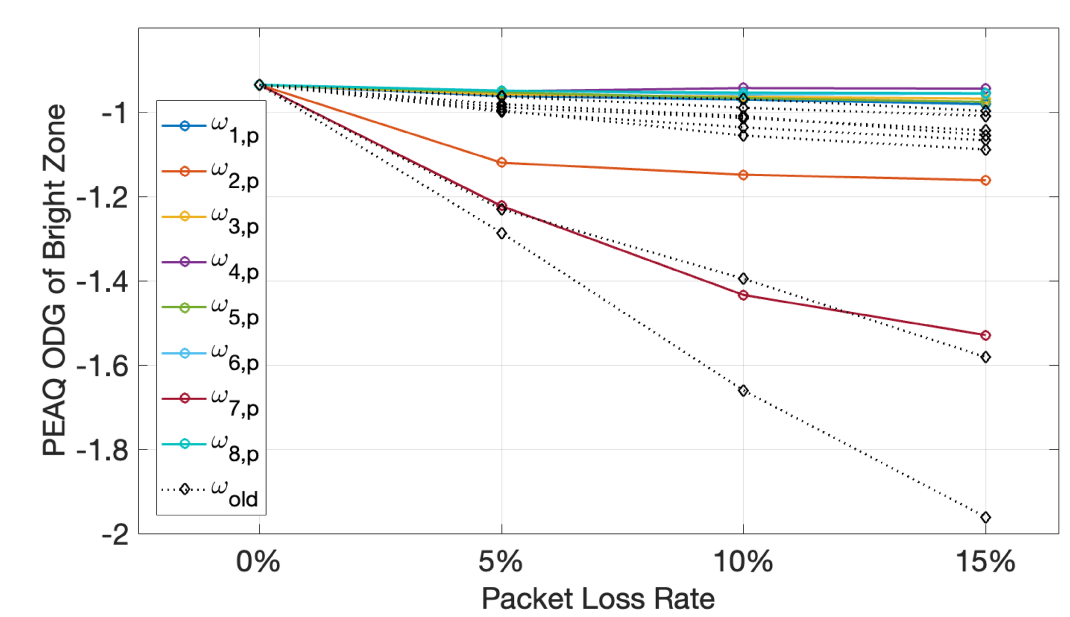
(——) ω_{old}, no packet loss, (——) $\omega_{5,10\%}$, no packet loss,
(- - -) ω_{old}, 10% packet loss, (- - -) $\omega_{5,10\%}$, 10% packet loss.

- **Mean Contrast** of old and proposed filters with p = 5%, 10%, 15% packet losses.



Our new filters generally have **higher Mean Contrast**.

- **PEAQ ODG** of the bright zone for old and proposed filters with p = 5%, 10%, 15% packet losses.



Our new filters reproduce **higher quality of audio**.