AASP-P7.4

Global and Local Mode-domain Adaptive Algorithms for Spatial Active Noise Control Using Higher-order Sources

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1. Background & Abstract

- **Spatial active noise control** (**ANC**) aims to attenuate noise over a certain space
- A large-scale system is required to achieve it
- **A higher-order source** (**HOS**) [1] has advantages in sound field control because it has controllable directivity patterns and occupies a smaller physical space

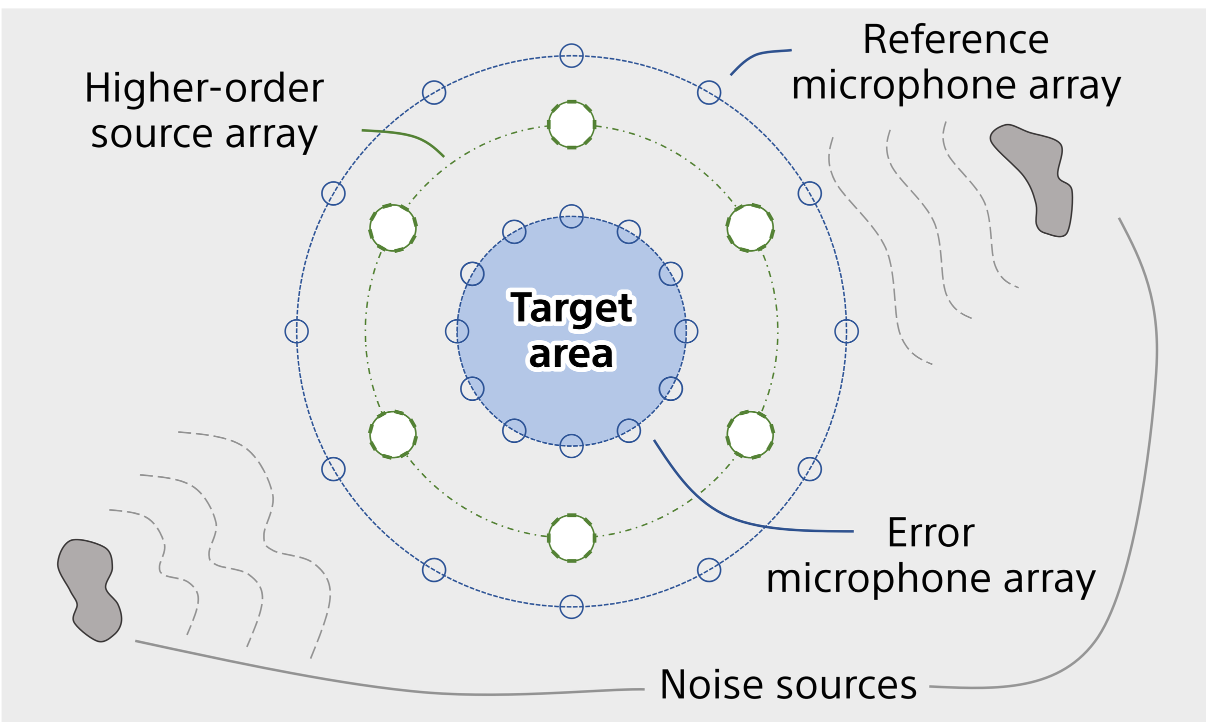
▶ Spatial ANC methods using **HOSs** are proposed

▶ Proposed methods are based on **the mode-domain signal processing** **[2]** which achieves fast convergence and a low computational cost

2. Problem Formulation

2.1. Array configuration

- Three concentric equiangular transducer arrays
- An objective of spatial ANC here is to attenuate noise in **the target area**



2.2. Harmonic representation of sound field

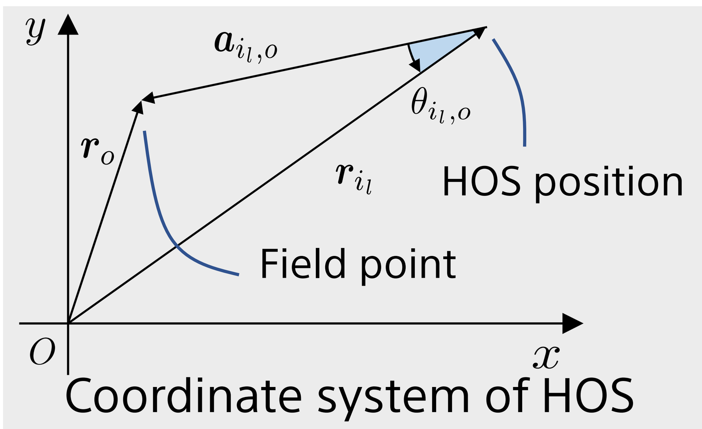
- The target sound field is represented using **the harmonic representation**

$$p(\mathbf{r}) = \sum_{m_g=-M_g}^{M_g} J_{m_g}(kr)\gamma_{m_g}(k)e^{-jm_g\phi}$$

Target sound field — $p(\mathbf{r})$; **Global mode coefficients** — $\gamma_{m_g}(k)$

2.3. Higher-order sources

- The sound field generated by **HOSs** [1] (which are located at $\mathbf{r}_{i_1},\cdots,\mathbf{r}_{i_L}$) is derived



$$p(\mathbf{r}_o) = \sum_{i_l,m_l} y_{m_l,i_l} H^{(2)}_{m_l}(ka_{i_l,o})e^{-jm_l\theta_{i_l,o}}$$

Cylindrical addition theorem

$$= \sum_{m_g,i_l,m_l} y_{m_l,i_l} H^{(2)}_{m_g+m_l}(kr_l)J_{m_g}(kr_o)e^{-jm_g(\phi_o-\phi_{i_l})}$$

Local mode coefficients of each HOS — y_{m_l,i_l}

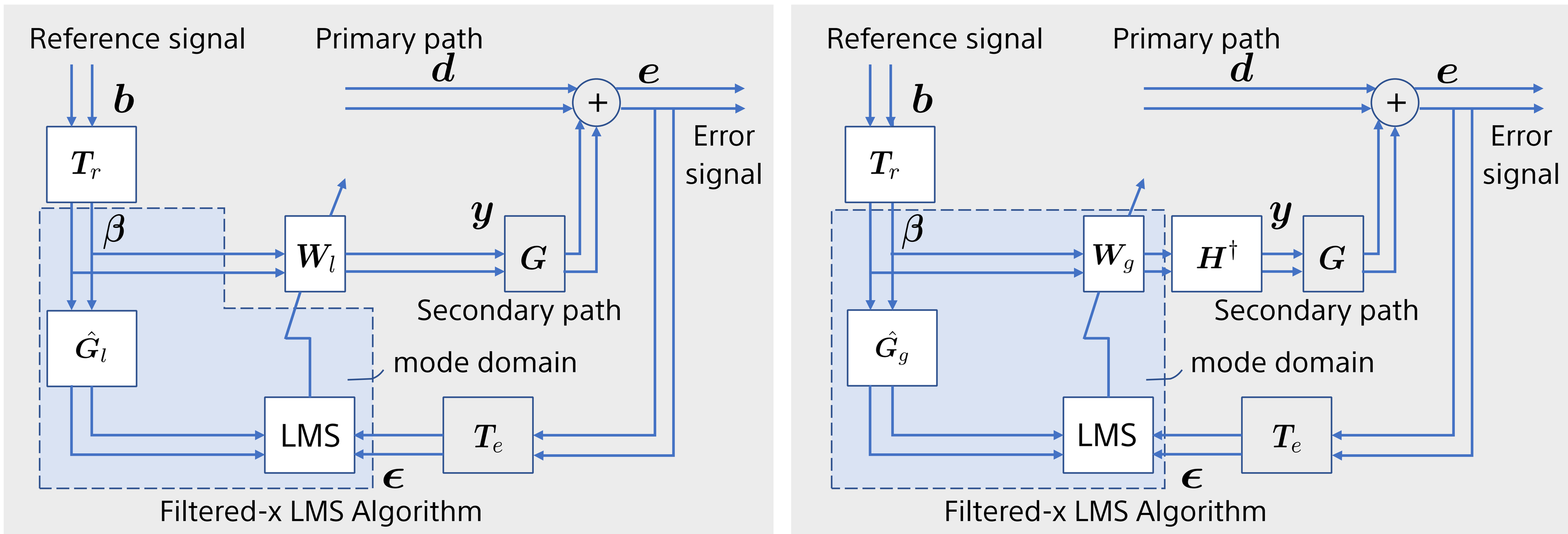
Relationship between global mode coefficients and local mode coefficients

$$\boldsymbol{\gamma} = \boldsymbol{g}\boldsymbol{H}\boldsymbol{y}$$

- $\boldsymbol{\gamma}$: **Global mode coefficients**
- $\boldsymbol{g}$: Acoustic transfer function in global mode domain
- $\boldsymbol{H}$: Transformation matrix between local and global mode domain
- $\boldsymbol{y}$: **Local mode coefficients**

3. Proposed Algorithms

Block diagrams and error function



LM algorithm   **GM** algorithm

- Both algorithms minimize the instantaneous squared error of **the global mode coefficients**

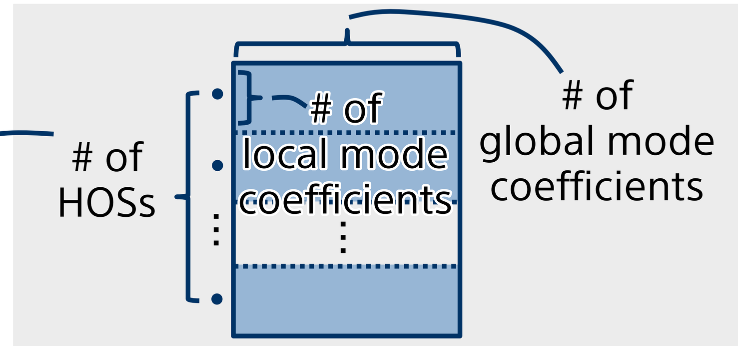
$$J_g(\boldsymbol{\epsilon}(n)) = \boldsymbol{\epsilon}^H(n)\boldsymbol{\epsilon}(n) \simeq$$

Approximation value of total error in target area [2]

3.1. Local mode-domain adaptive algorithm (LM)

System model

$$\boldsymbol{\epsilon} = \boldsymbol{\gamma} + \boldsymbol{T}_e\boldsymbol{G}\boldsymbol{W}_l\boldsymbol{\beta}$$



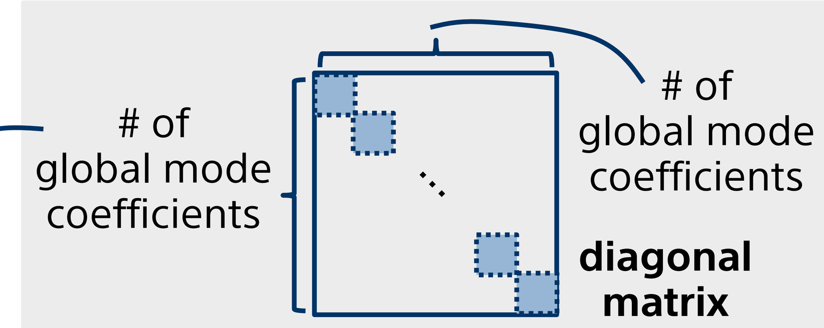
Filter update rule derived by LMS

$$\boldsymbol{W}_l(n+1) = \boldsymbol{W}_l(n) - \mu\hat{\boldsymbol{G}}_l^{\,H}\boldsymbol{\epsilon}(n)\boldsymbol{\beta}^H(n) \quad \text{where } \hat{\boldsymbol{G}}_l = \boldsymbol{T}_e\hat{\boldsymbol{G}}$$

3.2. Global mode-domain adaptive algorithm (GM)

System model

$$\boldsymbol{\epsilon} = \boldsymbol{\gamma} + \boldsymbol{T}_e\boldsymbol{G}\boldsymbol{H}^\dagger\boldsymbol{W}_g\boldsymbol{\beta}$$



Filter update rule derived by LMS

$$\boldsymbol{W}_g(n+1) = \boldsymbol{W}_g(n) - \mu\hat{\boldsymbol{G}}_g^H \mathrm{diag}\left(\boldsymbol{\epsilon}(n)\circ\overline{\boldsymbol{\beta}(n)}\right)$$

where $\hat{\boldsymbol{G}}_g = \mathrm{diag}\left((\boldsymbol{T}_e\hat{\boldsymbol{G}}\boldsymbol{H}^\dagger)_{-M_g,-M_g},\cdots,(\boldsymbol{T}_e\hat{\boldsymbol{G}}\boldsymbol{H}^\dagger)_{M_g,M_g}\right)$

Estimated secondary path in global mode domain

3.3. Comparison between proposed algorithms

Computational cost

Filtering:	GM	≤	LM	<	MIMO
Filter update:	GM	≪	LM	<	MIMO

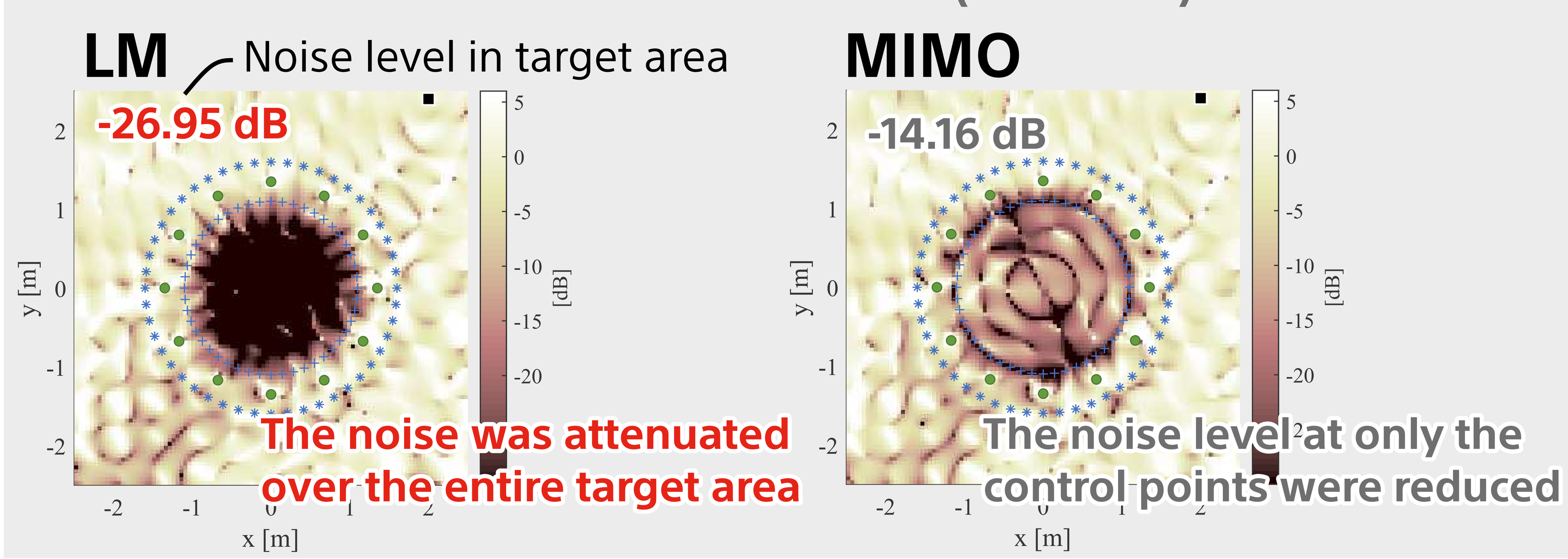
HOS array configuration

- LM algorithm does not necessarily require a **circular equiangular** HOS array

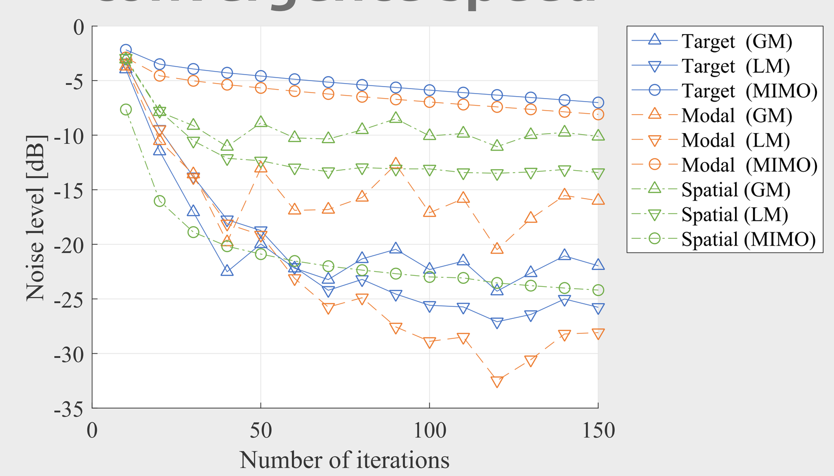
4. Experiment

- **LM**, **GM**, and MIMO (baseline) were compared

Noise level in dB after 500 iterations (at 500Hz)

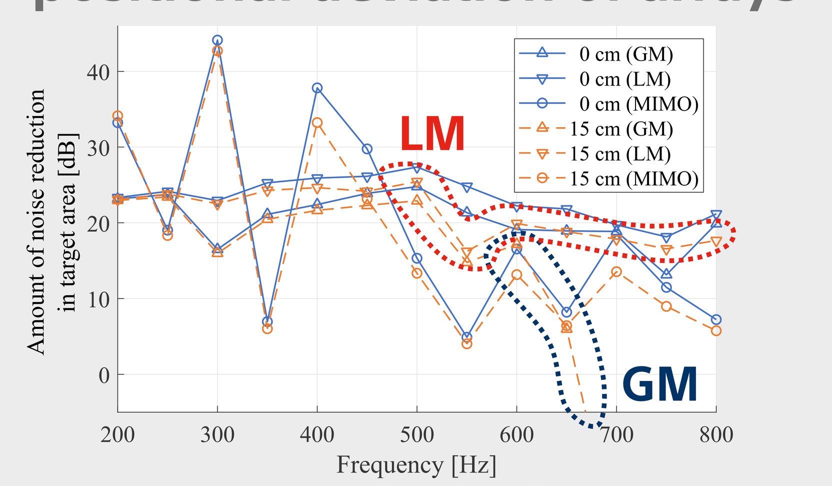


Comparison of convergence speed



GM and LM achieved rapid convergence

Robustness against positional deviation of arrays



LM had robustness against the deviation

Reference:
[1] M. A. Poletti, et al., *IEEE ICASSP*, 2011. [2] J. Zhang, et al., *IEEE TASLP*, 2018.