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CHANNEL ESTIMATION FOR CROSSTALK CANCELLATION IN WIRELESS ACOUSTIC NETWORKS

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1. Crosstalk Canceller (CC) over a WASN

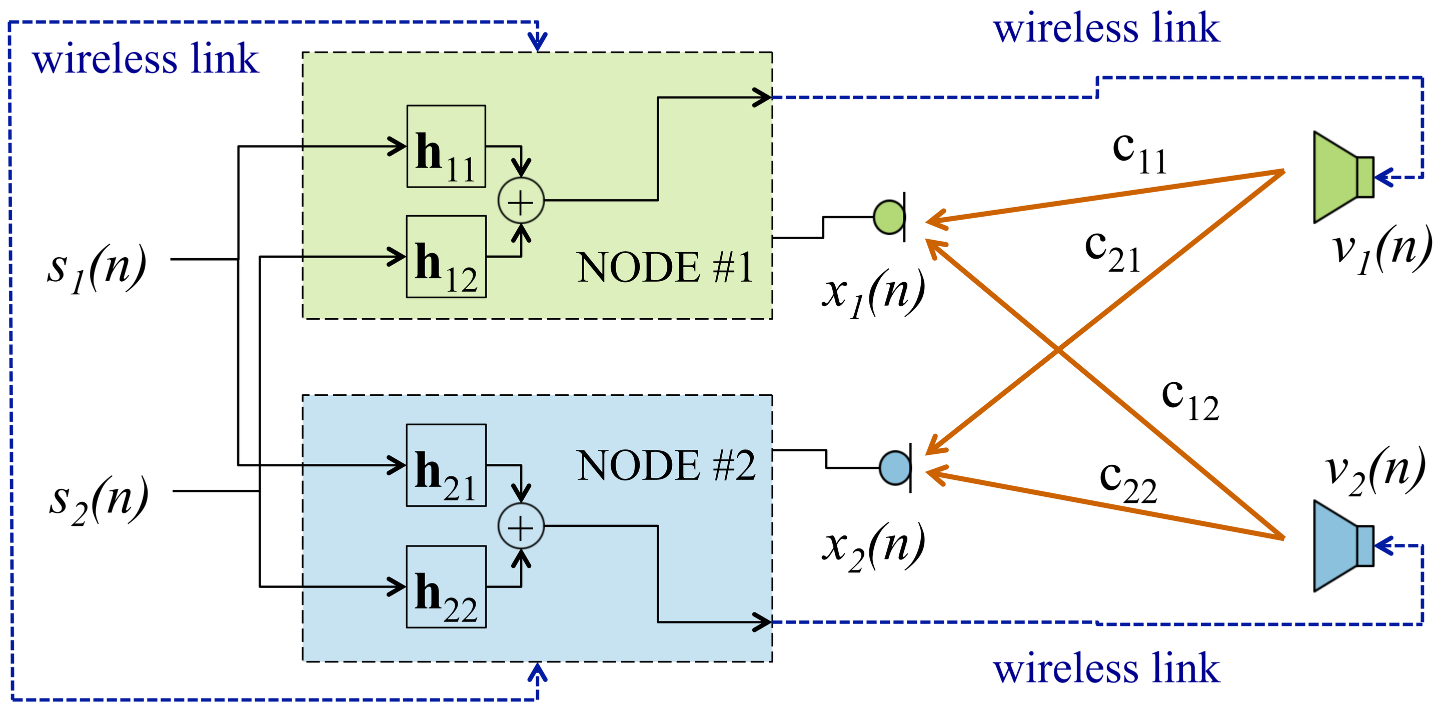
WASN: Wireless Acoustic Sensor Network

ORIGINAL SOUNDS

- $s_1(n)$: (e.g. Male speech)
- $s_2(n)$: (e.g. Female speech)

CC DESIRED RESPONSE

- $x_1(n) \approx s_1(n)$
- $x_2(n) \approx s_2(n)$



Step 1) > Estimate the **electro-acoustic channels** (also called Room Impulse Responses, **RIR**) $\mathbf{c}_{ij}$ using maximum length sequences (MLS) [1].

$$\mathbf{c}_{ij} = [\ c_{ij}(0) \quad c_{ij}(1) \quad \cdots \quad c_{ij}(L_c-1)\ ]^T$$

Step 2) > Design the **CC filters** $\mathbf{h}_{ij}$ [2].

Step 3) > Filter original signals $s_1(n)$ and $s_2(n)$ through filters $\mathbf{h}_{ij}$ to obtain $v_1(n)$ and $v_2(n)$. Provide the desired signals $x_1(n)$ and $x_2(n)$ at the mic locations.

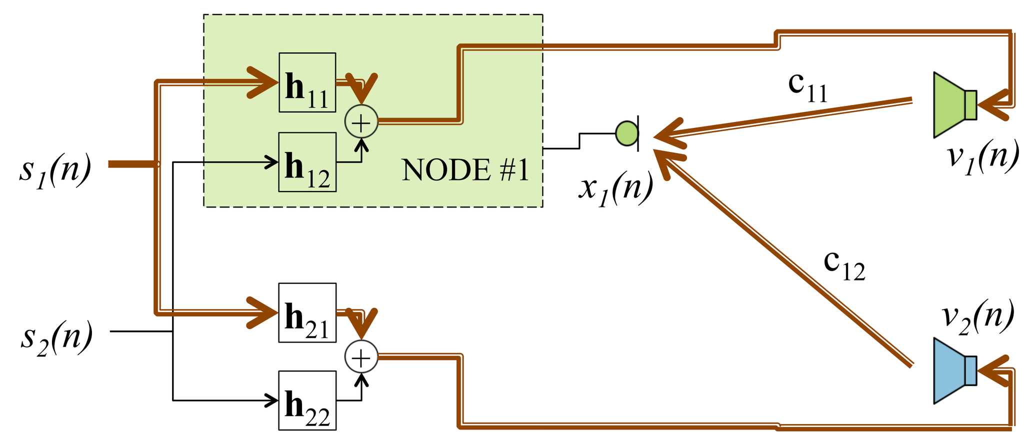
Some challenges due to the use of WASNs:

- Lack of perfect synchronization between the nodes [3].
- Requirement of low communication burden between nodes, thus, no exchange of signals $x_i(n)$ or $v_i(n)$ is allowed.
- **The acoustic channels $\mathbf{c}_{ij}$ can vary their coefficients due to changes in the location of the nodes.**

[1] J. Vanderkooy, "Aspects of MLS measuring systems," J. Audio Eng. Soc, vol. 42, no. 4, pp. 219–231, 1994.
[2] O. Kirkeby et al., "Fast deconvolution of multichannel systems using regularization," *IEEE Trans. on Speech and Audio Processing*, vol. 6, no. 2, pp. 189-194, Mar 1998.
[3] G. Piñero *et al.*, "Sound-field reproduction system over a two-node acoustic network of mobile devices," *Proc. IEEE 2nd World Forum on Internet of Things (WF-IoT)*, Milan, 2015, pp. 652-657.

2. Adaptive identification of the acoustic channels

Let us define the **Global Impulse Response (GIR)** $\mathbf{a}_{11}$ of NODE #1 as the impulse response between $s_1(n)$ and $x_1(n)$:



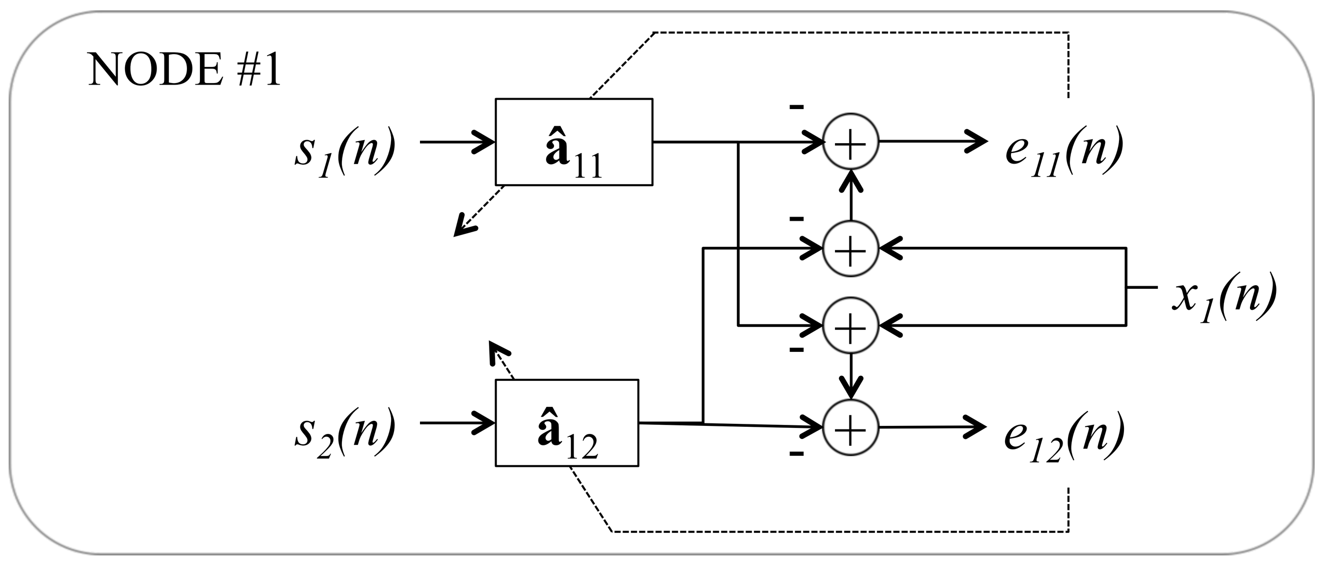
$$\mathbf{a}_{11} = \mathbf{c}_{11} * \mathbf{h}_{11} + \mathbf{c}_{12} * \mathbf{h}_{21}$$

We define in the same way the GIR between $s_2(n)$ and $x_1(n)$ as:

$$\mathbf{a}_{12} = \mathbf{c}_{11} * \mathbf{h}_{12} + \mathbf{c}_{12} * \mathbf{h}_{22}$$

Therefore: $$x_1(n) = \mathbf{a}_{11} * s_1(n) + \mathbf{a}_{12} * s_2(n)$$

Adaptive estimation of the GIRs



Step 1) > The estimation of the GIRs related to NODE #1 is carried out minimizing the mean square of the following error signals:

$$e_{11}(n) = [x_1(n) - \hat{\mathbf{a}}_{12} * s_2(n)] - \hat{\mathbf{a}}_{11} * s_1(n)$$

$$e_{12}(n) = [x_1(n) - \hat{\mathbf{a}}_{11} * s_1(n)] - \hat{\mathbf{a}}_{12} * s_2(n)$$

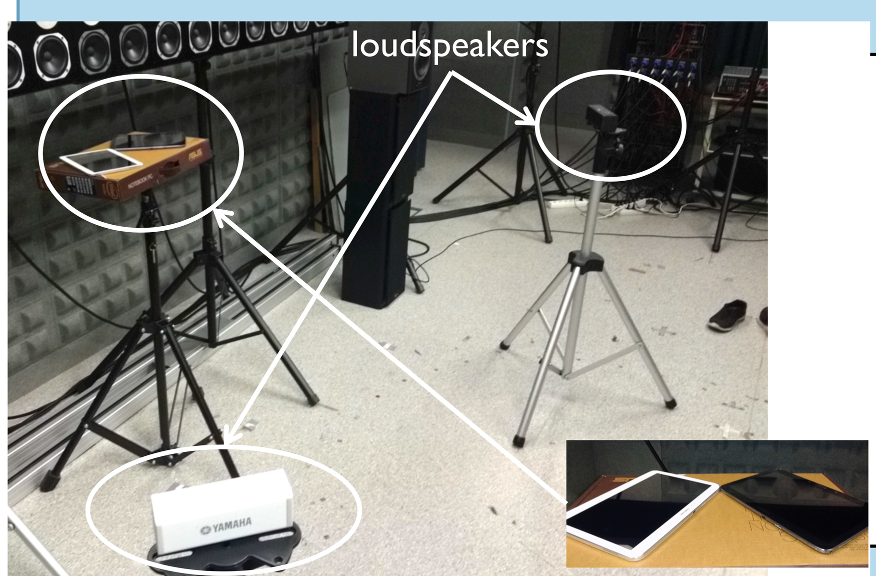
Similar procedure to estimate the GIRs associated to NODE #2 where:

$$\mathbf{a}_{21} = \mathbf{c}_{21} * \mathbf{h}_{11} + \mathbf{c}_{22} * \mathbf{h}_{21} \quad , \quad \mathbf{a}_{22} = \mathbf{c}_{21} * \mathbf{h}_{12} + \mathbf{c}_{22} * \mathbf{h}_{22}$$

Step 2) > Once the GIRs have been estimated, the corresponding RIRs are estimated at each node through a least squares (LS) solution.

Step 3) > Follow steps 2) and 3) of the CC algorithm to design the new filters and provide signals $v_1(n)$ and $v_2(n)$ to the loudspeakers.

3. Simulation Results



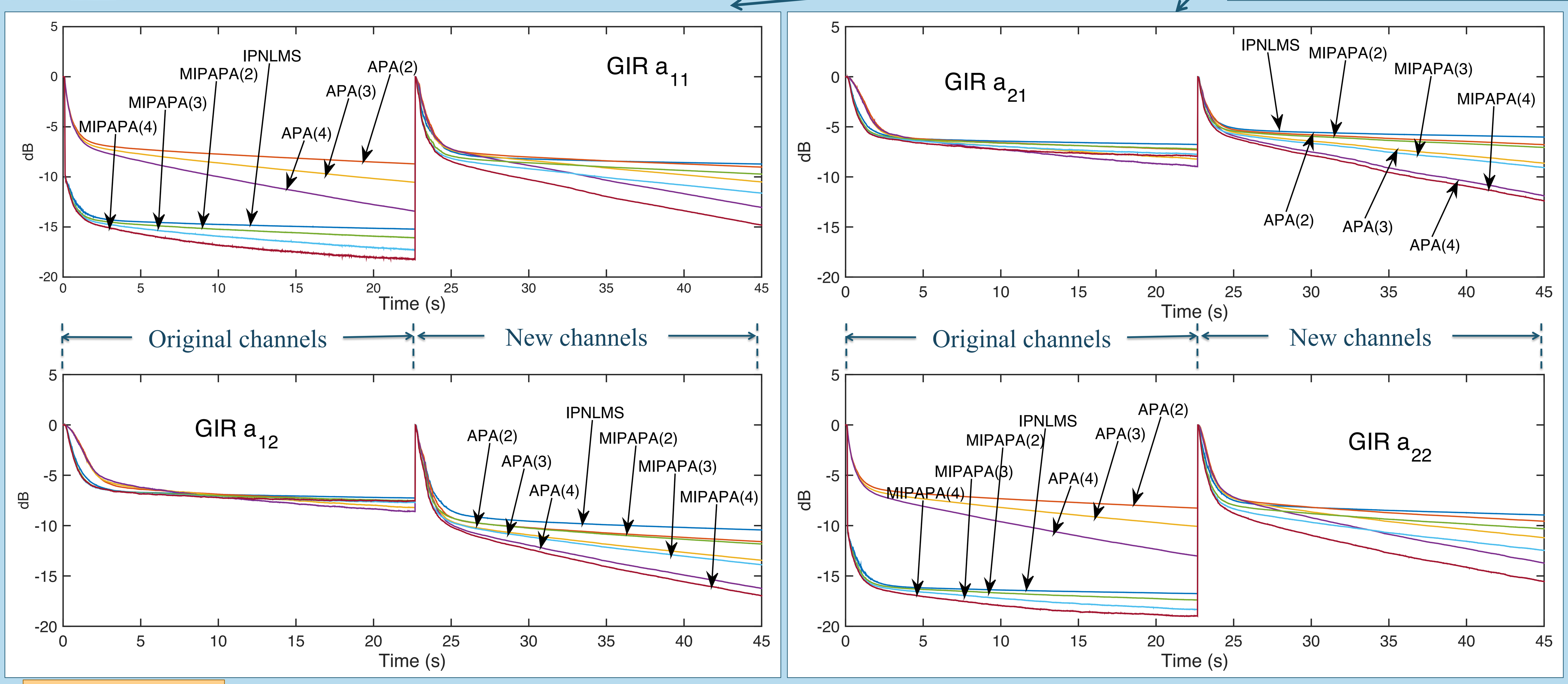
- Real acoustic channels measured between two Bluetooth loudspeakers & two tablets (Android OS).
- Number of RIR coefficients: L_c=1200.
- Sampling frequency f_s=11025 Hz.
- $s_1(n)$ and $s_2(n)$ are uncorrelated white noise.

Implemented algorithms

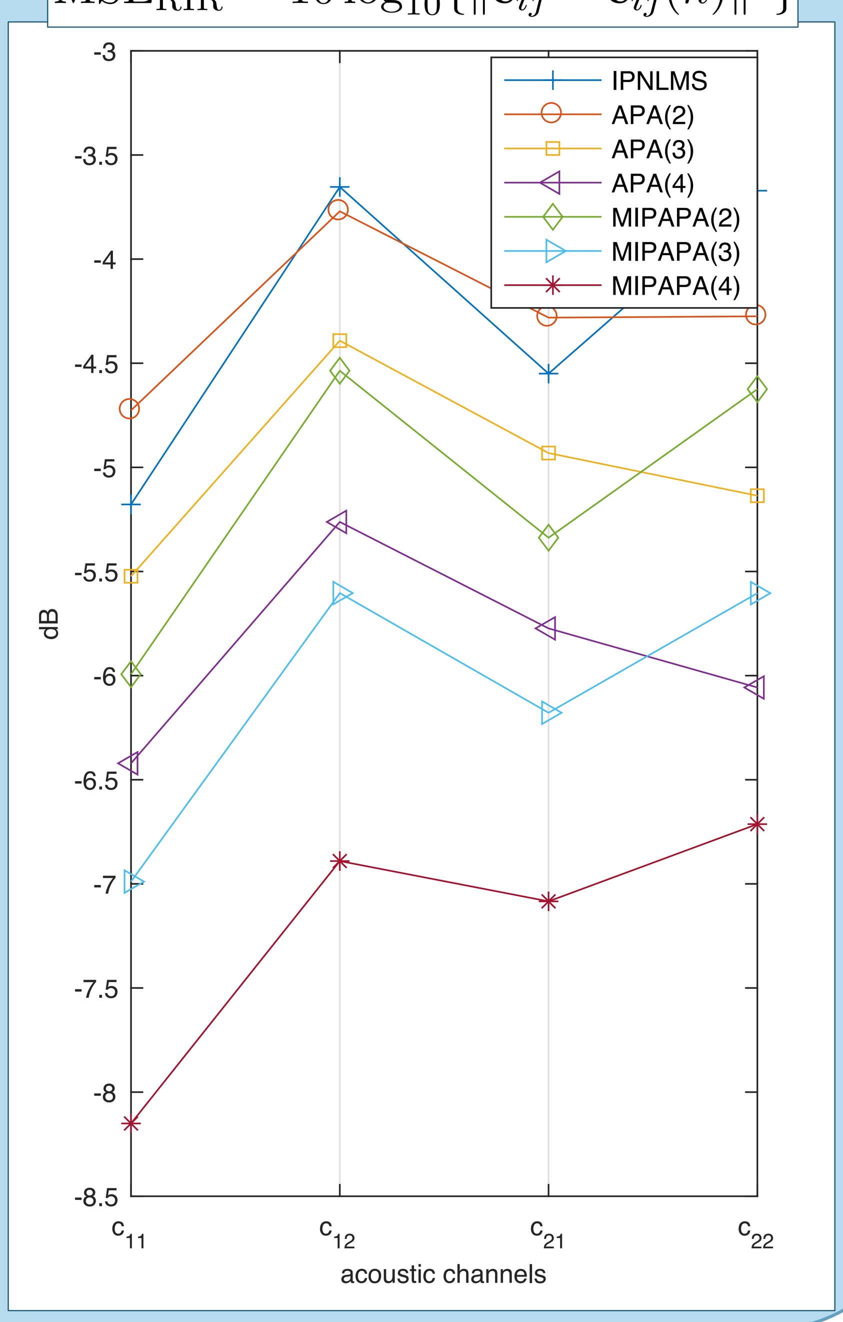
- Affine projection algorithm (APA), N=2,3,4
- Improved proportionate NLMS (IPNLMS)
- Memory-improved proportionate APA (MIPAPA) , N=2,3,4

For sparse GIRs

$$\text{Misalignment} = 20\log_{10}\frac{\|\mathbf{a}_{ij} - \hat{\mathbf{a}}_{ij}(n)\|_2}{\|\mathbf{a}_{ij}\|_2}$$



$$\text{MSE}_{\text{RIR}} = 10\log_{10}\{\|\mathbf{c}_{ij} - \hat{\mathbf{c}}_{ij}(n)\|^2\}$$



Conclusions

- GIR Estimation: MIPAPA of order N outperforms the corresponding APA of the same order.
- RIR Estimation: the MSE of MIPAPA of order N-1 is similar to that of APA of order N.