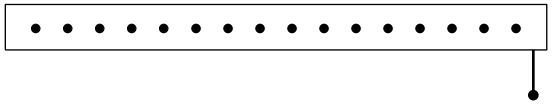
POLITECNICO
MILANO 1863

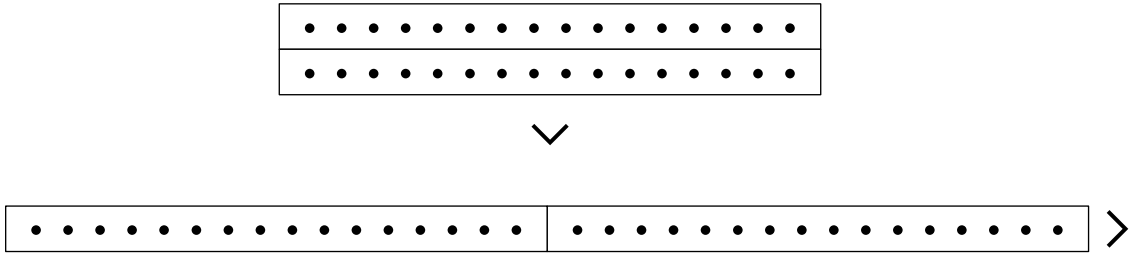
Acoustic Characterization of Uniform Linear Microphone Arrays

MAE Capstone – A.Y. 2023/2024

Introduction and goals



- *Eventide* **eStick V4**:
  - Uniform Linear Arrays;
  - Network-based Modular Microphone Array Systems (16 mic. elements per device);
  - Integrated *Audinate Dante*™ Power-over-Ethernet interface.



Introduction and goals

- **Frequency Response Cross Evaluation**
  - *Consistency* between different modules and between different capsules within the same device;
  - *Planar anisotropies* (consistency across the angular spectrum in the horizontal plane);

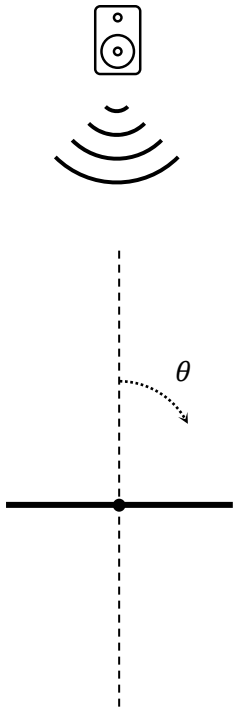
- **Direction of Arrival** (DoA) **Estimation** (*Application Test*).

→ When using *multiple devices*, it is important that the **response** of each one is **similar**:

  - the overall system can *accurately analyze the acoustic environment*, i.e. not introducing significant **variances** or **biases** that could *affect the integrity of the data*.

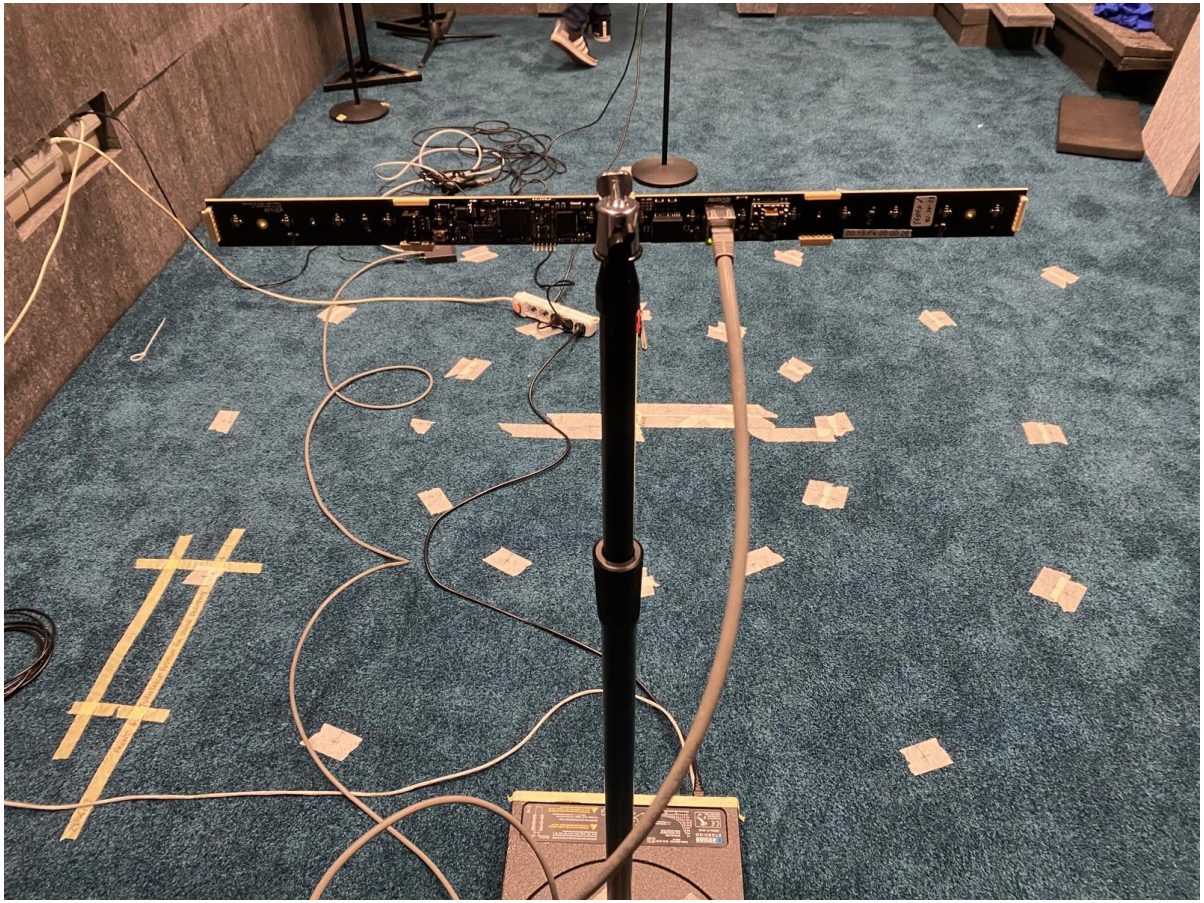
Operational Methodology

- *Semi-anechoic chamber*;
- Source Signal: **Exponential Frequency Sine Sweep** (50 Hz – 20 kHz);
- **36 Angular Positions** (10° apart);
- Response recorded in a *multichannel wave file* (16 channels, one per capsule);
- Standard **Deconvolution** Technique → RIRs.

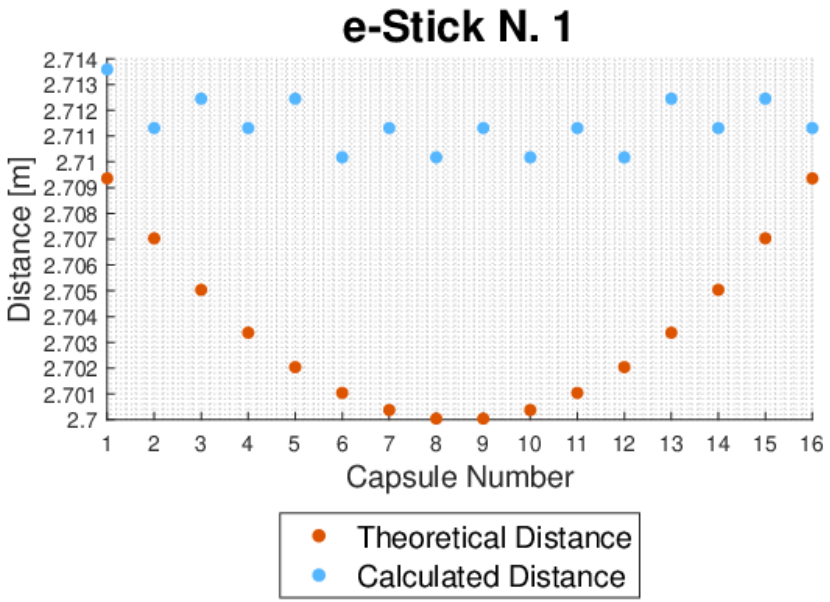


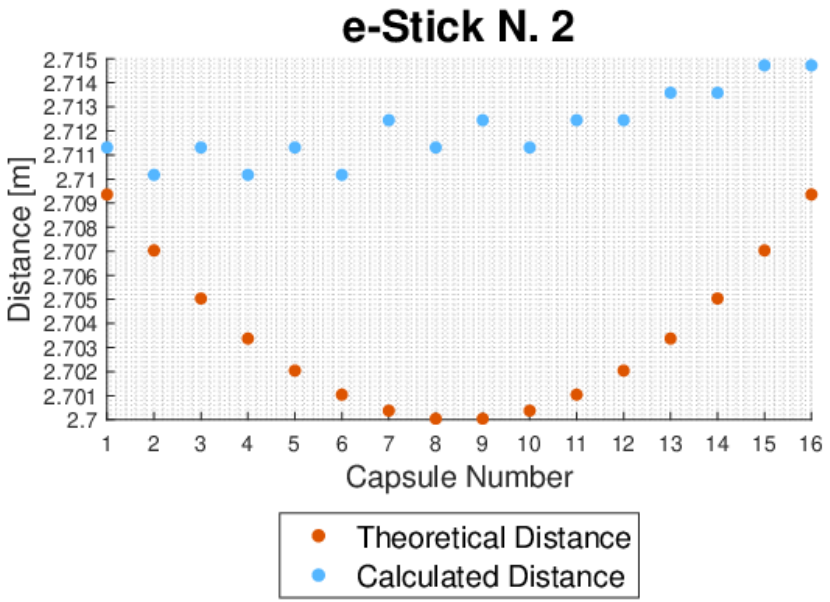
▷ A. Farina, “Advancements in impulse response measurements by sine sweeps,” *Audio Engineering Society Convention Paper*, May 2007.

Measurement Setup



Data Validation





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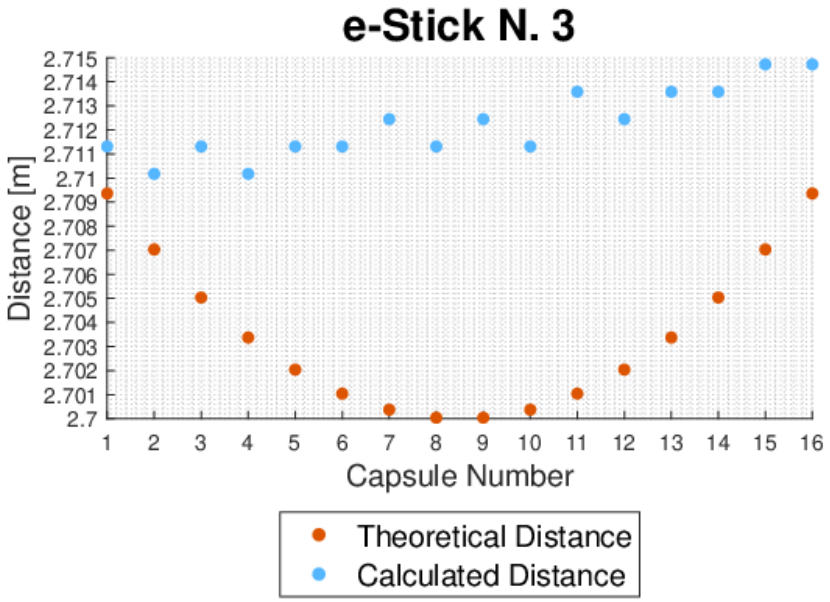
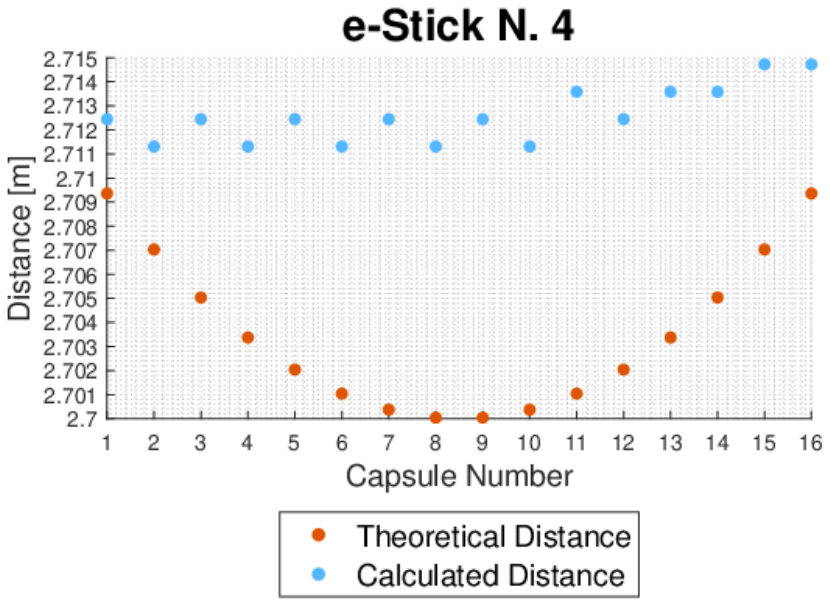
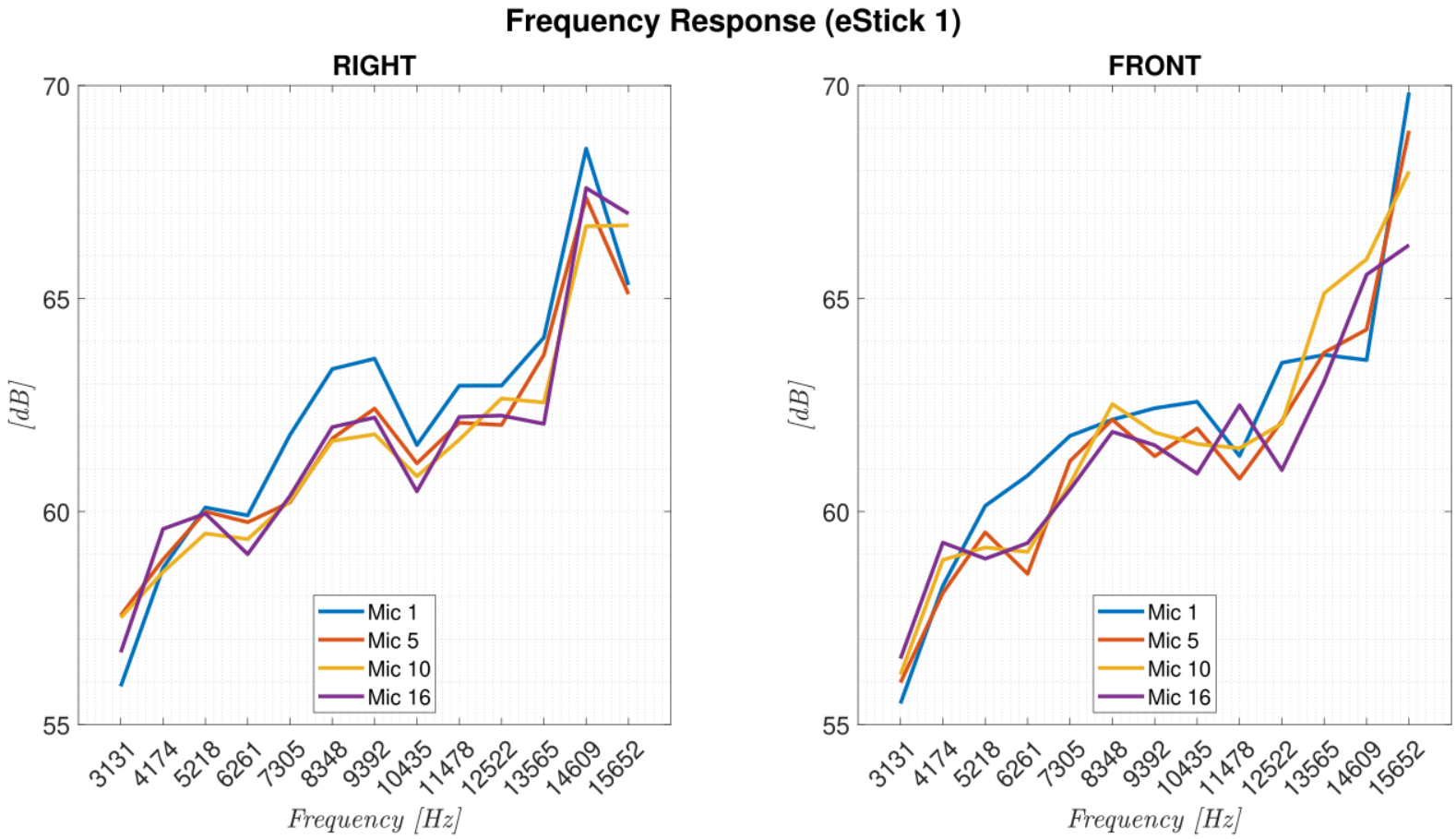


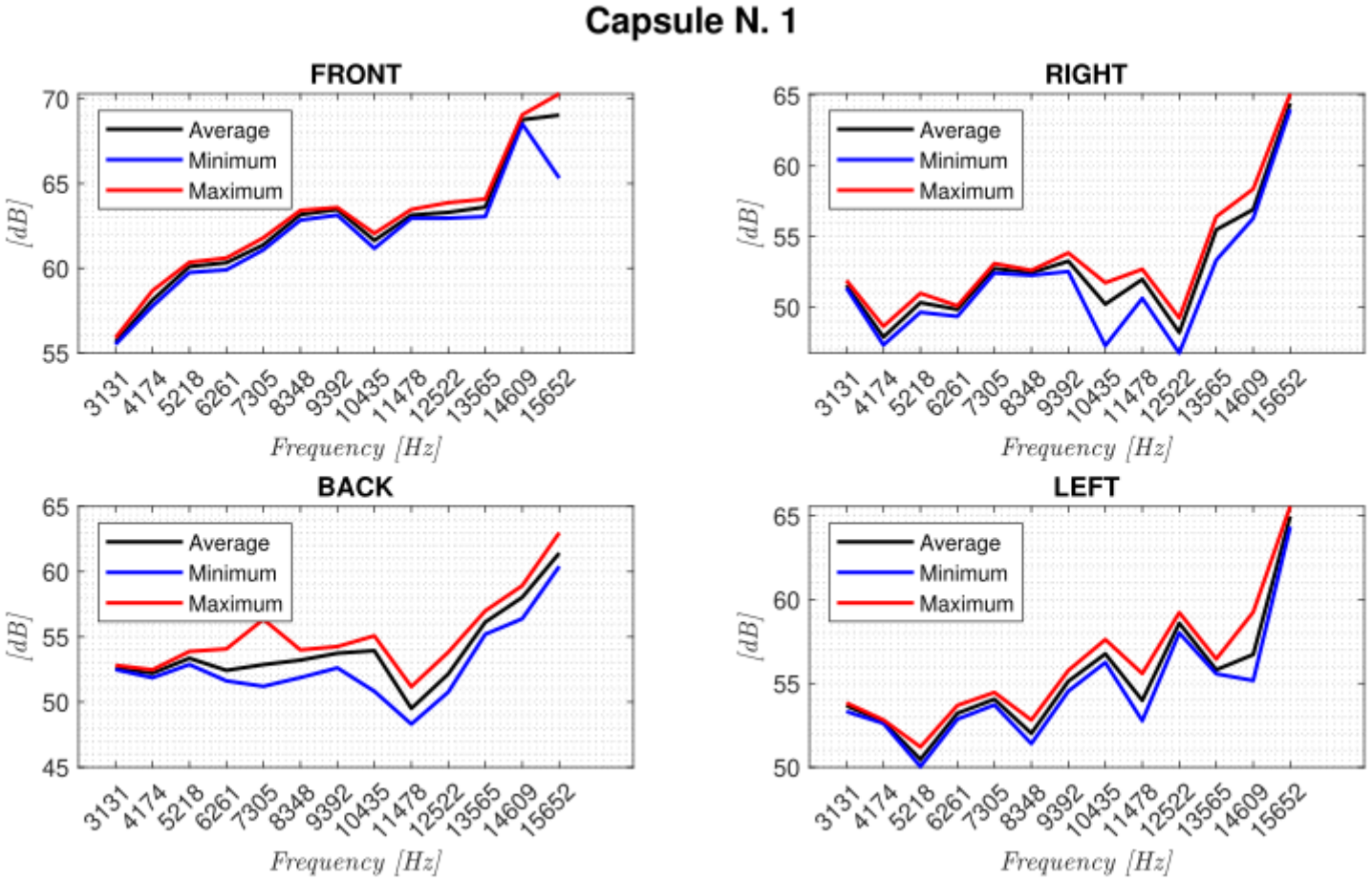


→| *Minor misalignment!*

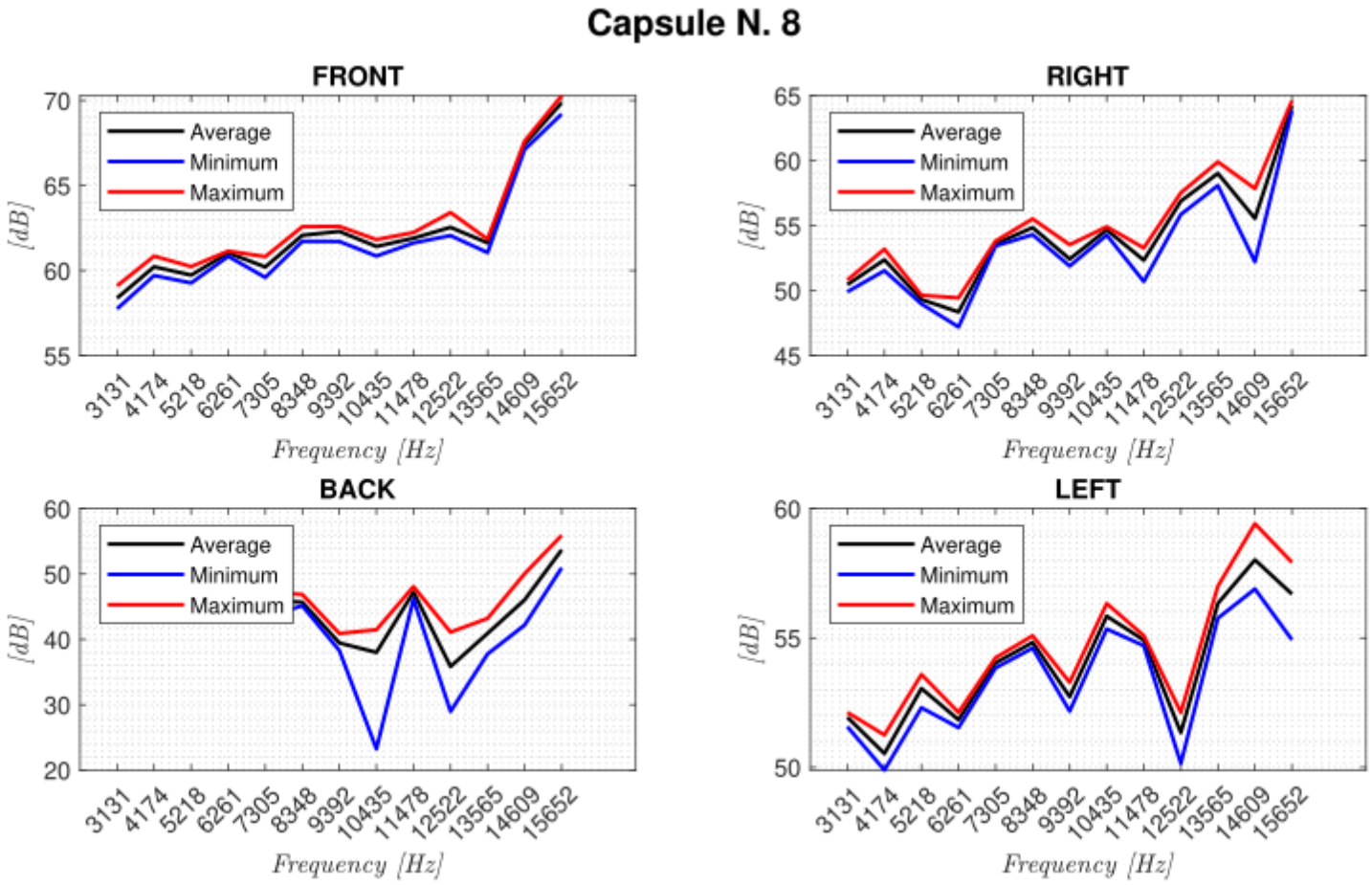
Data Validation



Frequency Response Cross Evaluation



Frequency Response Cross Evaluation



Frequency Response Cross Evaluation

- Behavior in line with expectations**:**
  - **Boost** due to **scattering** (*baffle*) after 3 – 4 kHz;
  - **Peak** at about 16 kHz;
  - The effect is *much less apparent for* $\theta = 90°, 180°$ especially *for outermost capsules* (less subject to scattering phenomena w.r.t. innermost ones).
- **Result**: the frequency response of a single capsule is ***consistent*** *across different modules*.
  - → Guaranteed **reliability** of measurements carried out by employing **multiple modules**.

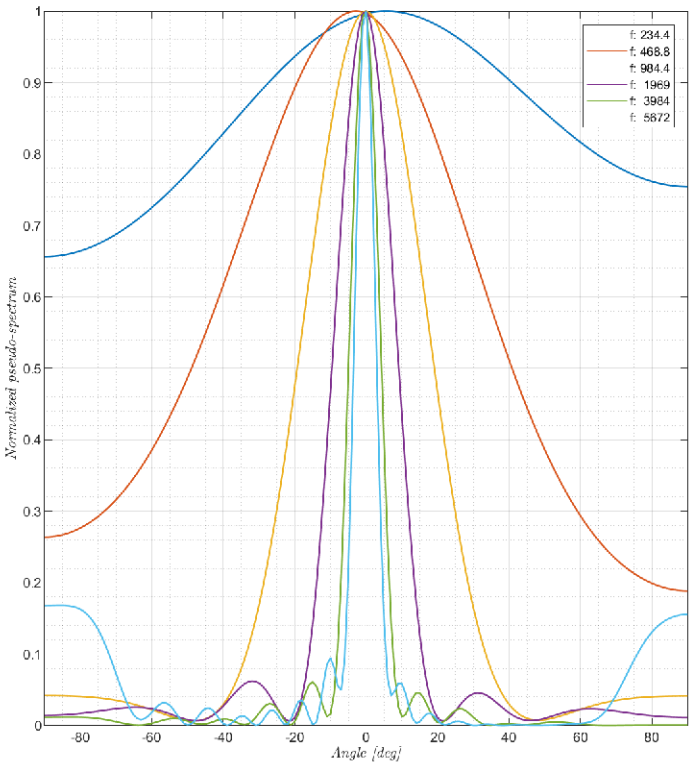
Direction of Arrival Estimation

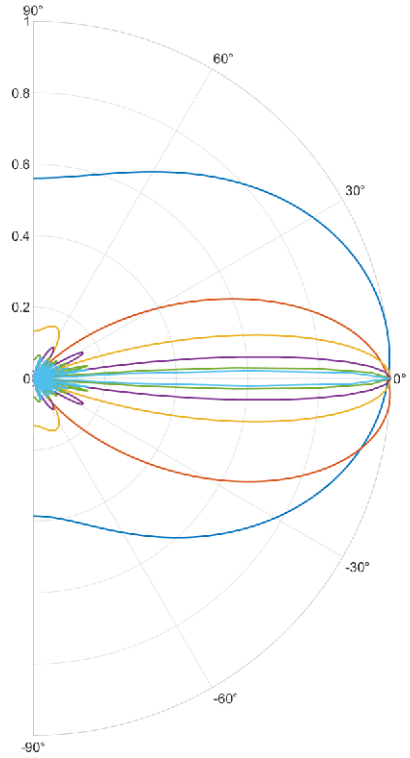
- *Practical Application*:
  - Tracking of the direction of arrival of a source signal;
- **Beamforming**: *Fourier-based spectral analysis of the spatially sampled data*;
- **Procedure**:
  - Sweeping of the angle of interest + beamforming operation (delay-and-sum beamforming) at each angle;
  - Peak detection in the resulting pseudospectrum.

▷ A. Canclini and A. Sarti, “Microphone arrays: spatial methods for doa estimation,” *Sound Analysis, Synthesis and Processing Course - Module 2: Sound Synthesis and Spatial Processing*, 2024.

Direction of Arrival Estimation

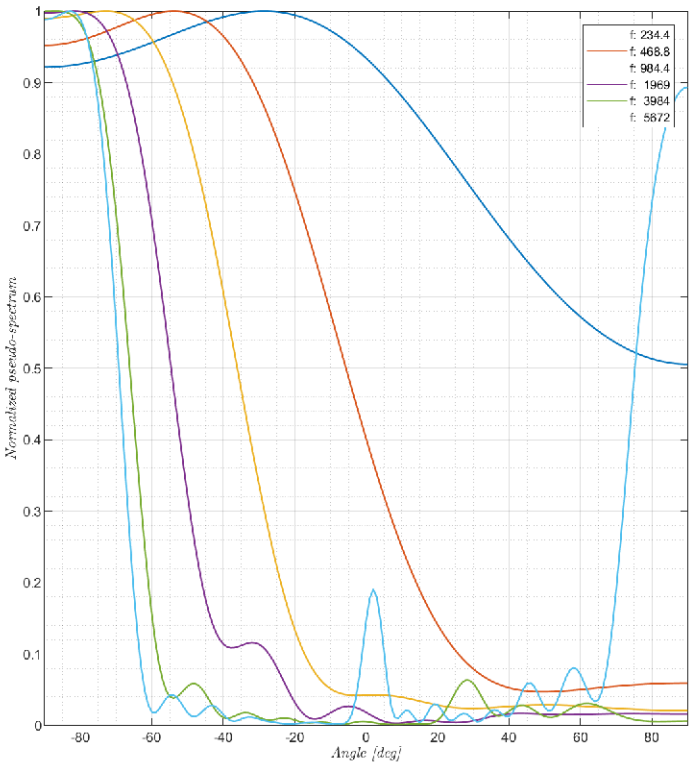
Stick: 1, Orientation: 0°

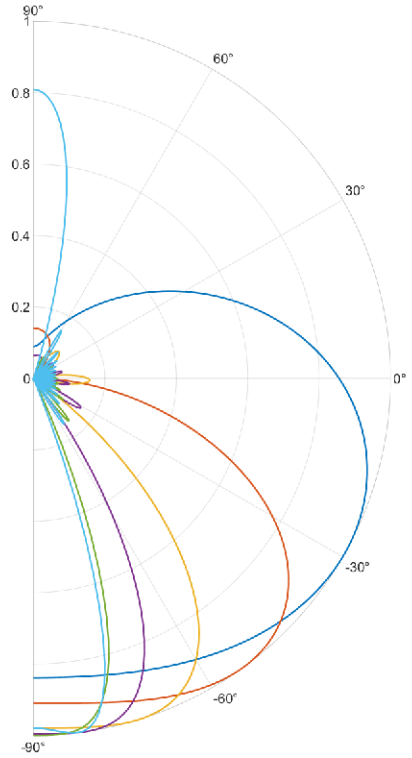




Direction of Arrival Estimation

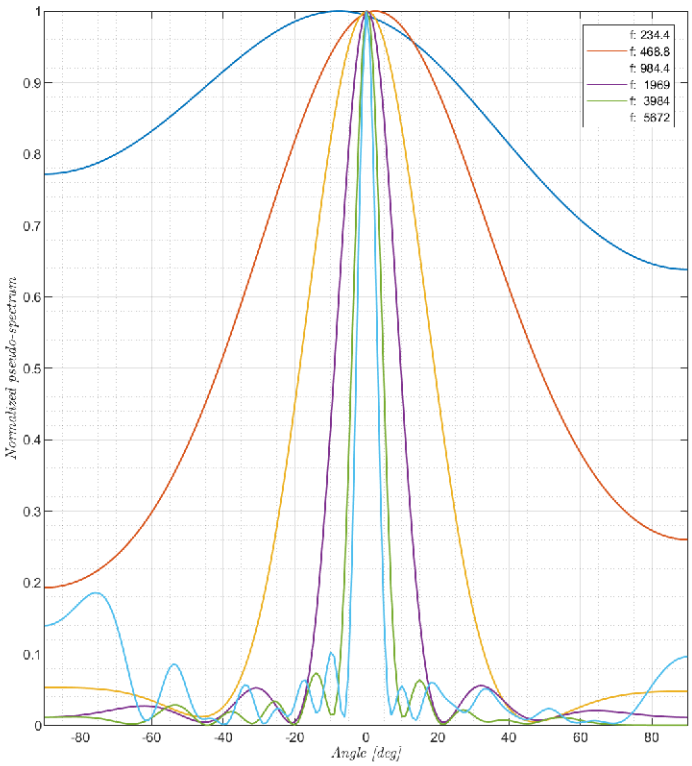
Stick: 1, Orientation: 90°

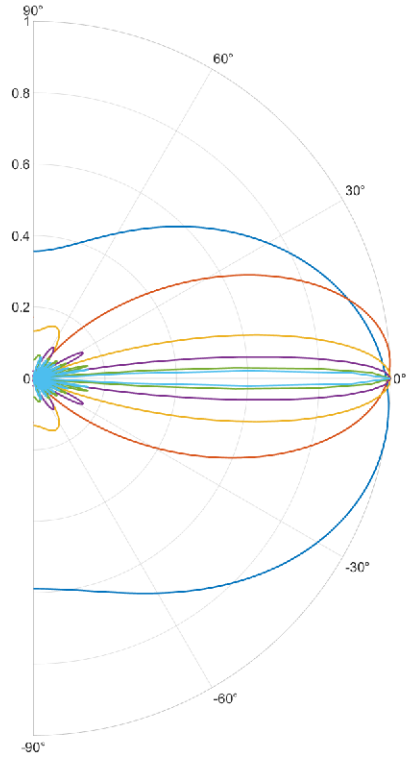




Direction of Arrival Estimation

Stick: 1, Orientation: 180°



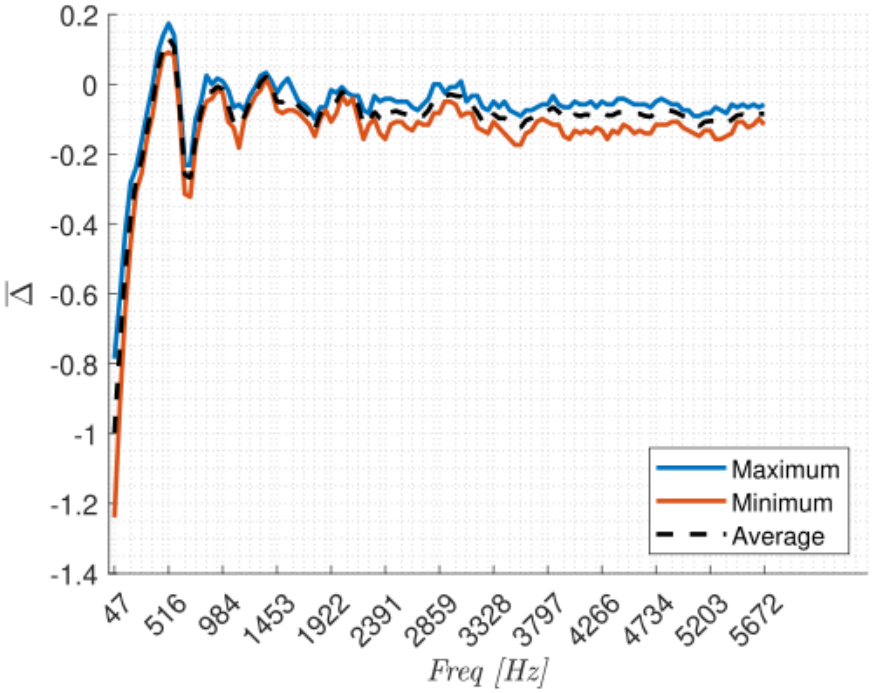


Direction of Arrival Estimation

- Error Parameter (difference between *estimate* and *ground truth*):

$$\Delta(\theta, f) = \mathrm{DOA}(\theta, f) - \theta$$

- Averaged across 36 angular positions;
- Evaluated for 121 frequency bins in the range 50 – 5600 Hz:
  - maximum frequency provided by anti-aliasing condition;
- **Higher accuracy at higher frequencies**, i.e. when the microphone directivity pattern is narrower;
- *Sistematic error* probably due to the light misalignment we already mentioned.



Successful procedure!

Conclusions

- *Eventide eSticks V4* are an **effective and consistent tool** to be employed in ***source tracking applications***.
- Major qualities: *ease of use* and, most of all, their **modularity**.
- Possible improvements and further in-depth analysis:
  - evaluation of the devices' performance beyond the horizontal plane (e.g. by varying also the inclination angle of the device);
  - different modular configurations to evaluate how different microphone distributions (alongside an extension of the device's baffle) may influence the overall performance;
  - more accurate and elaborate DOA estimation methods may be implemented.

Conclusions

The End!

Thank you for your attention.