OPTIMUM MEASUREMENT LOCATIONS FOR LOUDSPEAKER SYSTEM EQUALIZATION

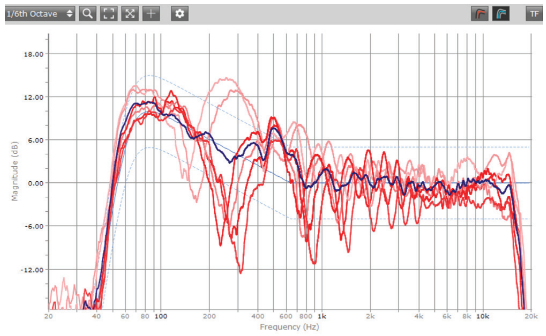
- **<u>Measurement area:</u> source coverage (¼ to ¾ in audience depth, away from walls)**
- **<u>Layout:</u> multi-locations spread in width and depth (no single line equidistant to side wall)**
- **<u>Minimum number:</u> 8 locations**

MEASUREMENTS FOR SYSTEM TUNING

A loudspeaker system tuning* ideally aims at optimizing the whole audience area. However, onsite EQ* choices must be based on a limited number of measured frequency responses*.

To avoid EQ mistakes, the key is to capture a representative set of measurements. It should:

- smooth spatial variations in the average frequency response,
- reveal spatially stable patterns in the individual frequency responses.



RECOMMENDATIONS FOR MULTI-LOCATIONS MEASUREMENT

Measurement area

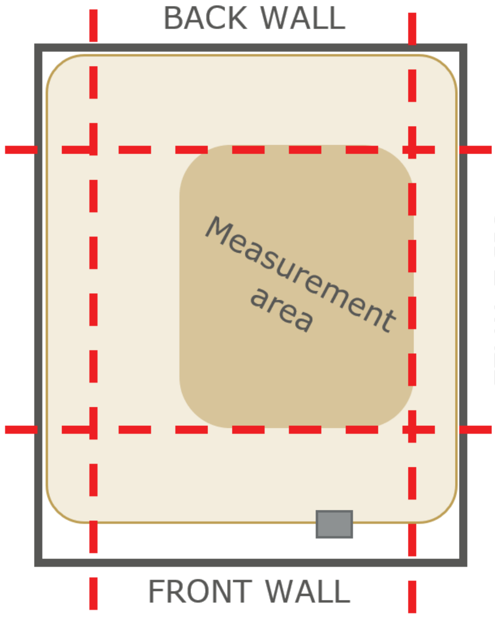
The measurement area should be limited to the coverage* of the source, within the central part of the audience depth, and away from the walls. This accounts for practical aspects such as limited accessibility of some areas at time of measurement. It also avoids polluting the data with very local irregularities that cannot be EQ anyway. These ones can originate from direct sound* itself or from reflections*, as listed below:

<u>Why avoiding first ¼ of the audience?</u>

- <u>Direct sound</u>: potential irregularities close to large line source deployments in the low-mid frequencies*.
- <u>Room reflections</u>: large variability of the front wall reflection.

<u>Why avoiding last ¼ of the audience?</u>

- <u>Direct sound</u>: lower measurement reliability with increasing distance (more reverberation than direct sound indoor and unstable atmospheric conditions outdoor).
- <u>Room reflections</u>: increased strength and variability of the back wall reflection.

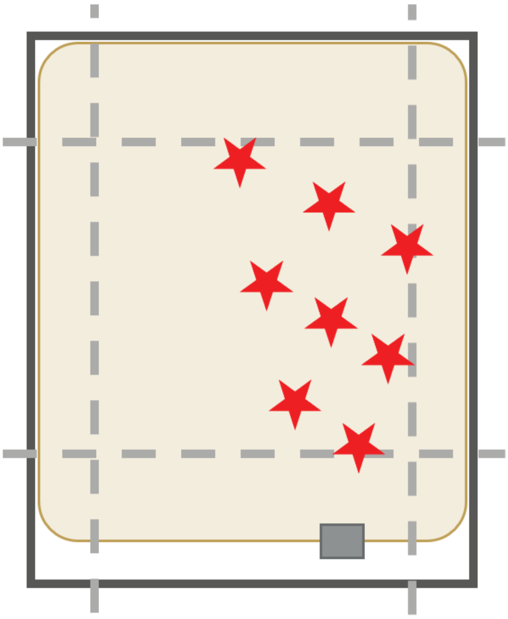


<u>Why not measuring close to the walls?</u>

Performing measurements at least 3 meters away from the walls avoids the areas of largest room reflection variability.

Measurement layout

The locations should be spread over the depth and width of the measurement area. For best representativity, it is recommended to implement a **Zebra layout**. This layout offers a good representativity in terms of characterization of the direct sound and strong room reflections.



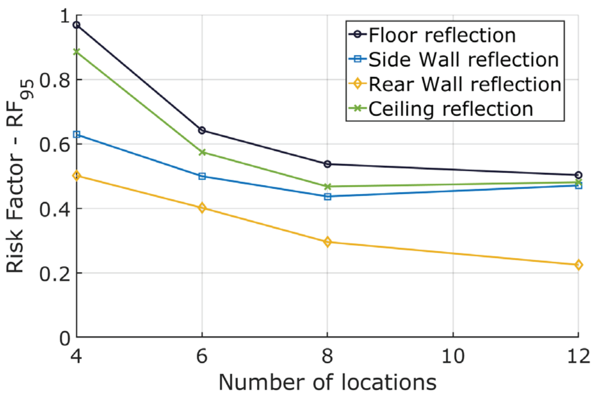
Why spreading out measurement locations in depth?

- Direct sound: it is more representative of the average tonal balance* over the audience area.
- Room reflections: it leads to a more representative measurement of the floor and ceiling reflections.

Why spreading out measurement locations in width?

- Direct sound: it adds accuracy by accounting for off-axis variations of the system response.
- Room reflections: it is more representative of the side wall reflection that strongly depends on the position in the room.

Note: in general, measurement layouts with locations parallel to the side wall should be avoided as it can induce observation of false stability effect that can lead to inappropriate tuning decisions.



Number of measurement locations

Increasing the number of locations lead to a more representative measurement of the system response over space. Nevertheless, there is no real benefit of using more than 8 locations when looking at the risk of making bad tuning decisions (see Risk Factor).

GLOSSARY

Coverage: Area over which the loudspeaker system provides a direct sound in an acceptable frequency response variation.

Direct sound: Sound wave that directly travels from the source to the receiver, being a listener or a microphone, without encountering any obstacle or boundary.

EQ / Equalization: Tool or process aimed at electronically adjusting the frequency response of an audio system.

Frequency response: Characterization of the frequency-dependent variations induced by an element of the system on the signal.

Low-mid frequencies: Frequency range between 250 Hz and 1000 Hz.

Reflection: Sound wave that has encountered a surface before reaching the receiver, being the listener or the microphone.

Reverberation: Sound that persists in an enclosed space, as a result of repeated reflections or scattering, after the sound source has stopped.

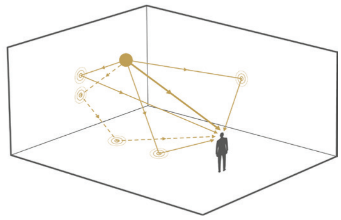
System tuning: Electronic optimization of the loudspeaker system performance through equalization and alignment techniques.

Tonal balance: Rough magnitude relation between different audio frequency ranges in either a response or a spectrum.

ANNEX 1: SPATIAL VARIABILITY OF STRONG REFLECTIONS

Simulations

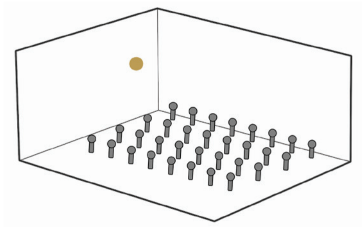
Simulations were conducted to study the spatial variability of the room strongest reflections over the audience area. This simulation framework was also used to assess the capability of different measurement layouts to capture representative data. Two rooms of simple geometry were used (shoe-box rooms with flat floor area of 15x20m and 45x60m). The numerical model considered an omnidirectional source and no wall absorption so that the strength of the reflections is not artificially limited.

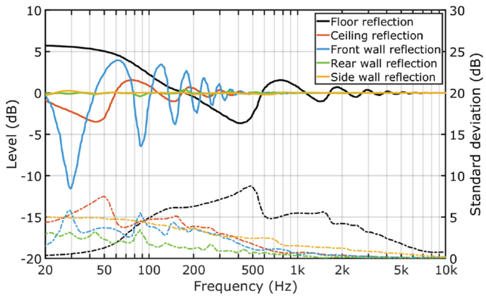


Reference responses of strong reflections

The average response over the entire source coverage area can be estimated with an exhaustive sampling of the area (a measurement location placed every meter). This response called reference response was assessed for each strong reflection in the room, coming from the floor, ceiling, front wall, back wall, or side wall.

These reference responses serve as targets to assess the representativity of various measurement configurations.





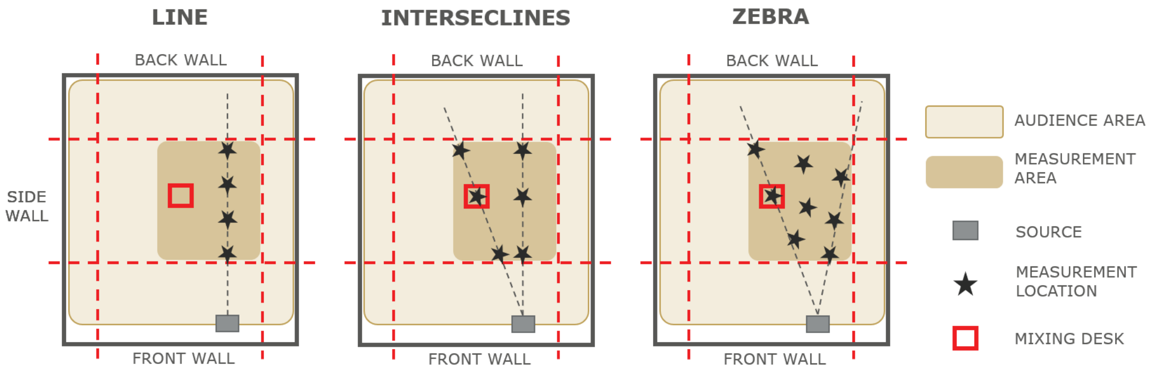
Reference responses: average magnitude response over the source coverage area (top) and associated standard deviation across locations (bottom).

ANNEX 2: MEASUREMENT CONFIGURATIONS

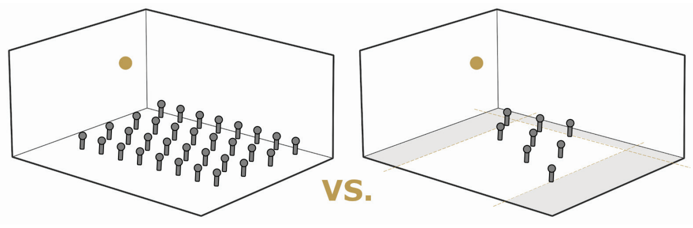
A measurement configuration is a given number of locations placed according to a given layout. The tested configurations were set of 4, 6, 8 or 12 locations, and 3 layouts inspired from field practices:

- **Line:** all the locations are on a line, on-axis of the source. This configuration was commonly used for optimization of zoning groups (not justified anymore with autosolver approach).
- **IntersecLines:** combination of two lines; one on-axis and the other off-axis of the source oriented toward the center of the audience with one measurement location at the mixing desk.
- **Zebra:** wider distribution of the locations, spread over the measurement area depth and width.

The measurement configurations were compared based on their risk of leading to a bad tuning decision (see Risk Factor).



ANNEX 3: RISK FACTOR



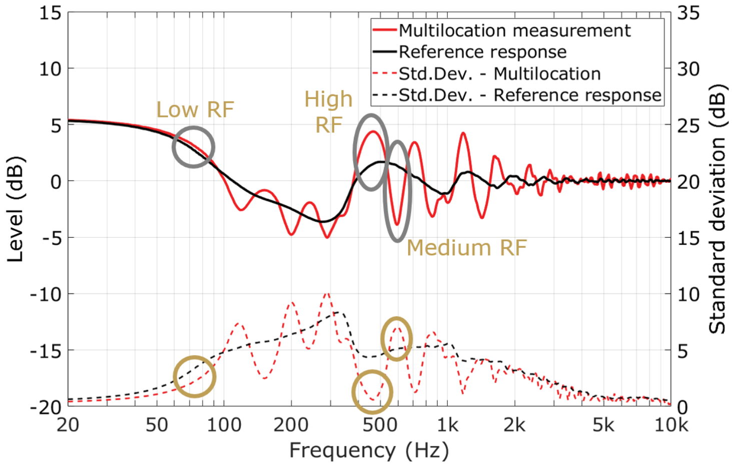
The Risk Factor was the evaluation criterion used to compare measurement configurations focusing on their risk of leading to bad tuning decisions.

To do so, the responses from the 4, 6, 8 or 12 locations of each configuration were averaged for each reflection individually and compared to the corresponding reference response (one reference response per reflection). The potential errors in frequency response of each configuration were weighted accounting for the consistency of the measurements across locations. The more consistent the measurements between locations, the more weight is given to the error in frequency response. This choice was made to better reflect the risk of applying an inappropriate tuning decision when the configuration tested showed an error in the response that appeared as consistent between measurements. At a given frequency, the higher the Risk Factor criterion the greater the risk of making a bad tuning decision.

Mathematically, the Risk Factor *RF(f)* can be described as:

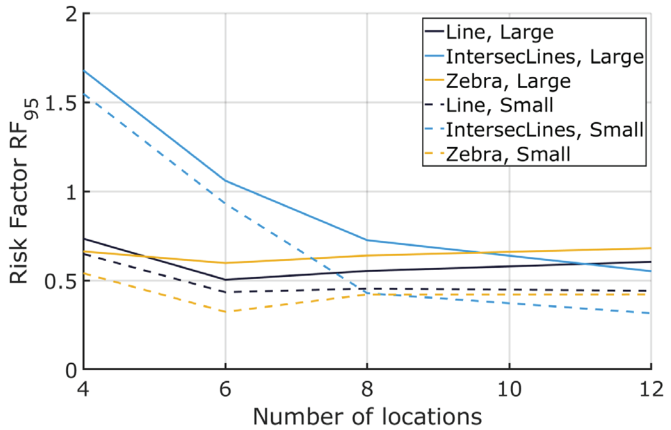
$$RF(f) = MRE(f) \cdot \frac{1}{1 + STD_{config}(f)}$$

where *MRE(f)* is the magnitude response error between the measurement configuration under test and the reference response, and $STD_{config}(f)$ is the standard deviation between the measurements of the configuration under test.



Example of frequency areas associated with low, medium or high Risk Factor for a given measurement configuration.

The maximum Risk Factor were calculated on the 20Hz-1kHz range for each measurement configuration. The maximum Risk Factor were then compared between the configurations to identify the ones that lead to less risk of making a bad tuning decision.



Maximum Risk Factor for the floor reflection in "Small" and "Large" rooms.