HOW TO OBTAIN STABLE MEASUREMENTS AT HIGH FREQUENCIES?

- **Avoid measurement at large distances (> approx. 60m) and rely on simulation for HF optimization, especially in windy conditions**
- **Multiply the number of sweeps: 8 sweeps outdoor, 4 sweeps indoor**

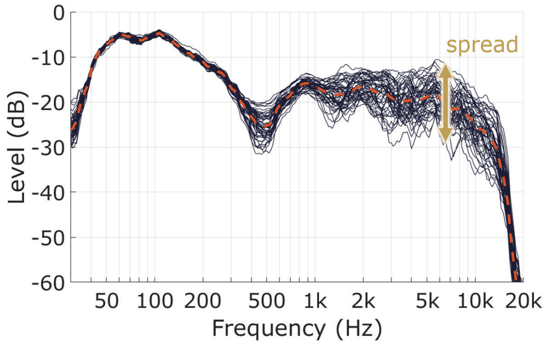
MULTI-SWEEP APPROACH

The frequency response* of a loudspeaker system can vary over time due to changing atmospheric conditions such as:

- temperature and humidity (slow variations),
- wind (fast variations).

Multiple acquisitions may reveal a large spread of frequency responses, especially at large distances and high frequencies*. This spread makes EQ* decisions taken from a single capture irrelevant.

In the M1 tool, multiple sweeps can be recorded and combined. The obtained **measurement** accounts for the fast variations of atmospheric conditions and offers a more reliable representation of the frequency response of a loudspeaker system.



RECOMMENDATIONS TO OBTAIN STABLE MEASUREMENTS

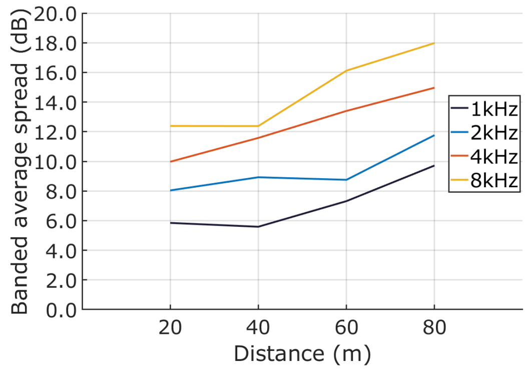
Influence of distance and frequency

The average spread of frequency responses typically increases with:

- distance to the source,
- frequency.

It is therefore recommended to **avoid measurements at large distances** (> approx. 60m) and to rely on simulations to optimize the system performance at high frequencies.

Note: HF spread is often critical outdoor due to wind effect but can be observed in large venues where Heating, Ventilation, and Air Conditioning systems (HVAC) favor air circulation.



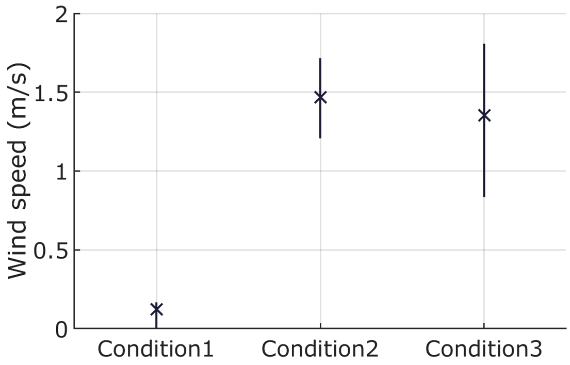
Example of average spread measured for different frequency bands at the Hollywood Bowl, CA, USA.

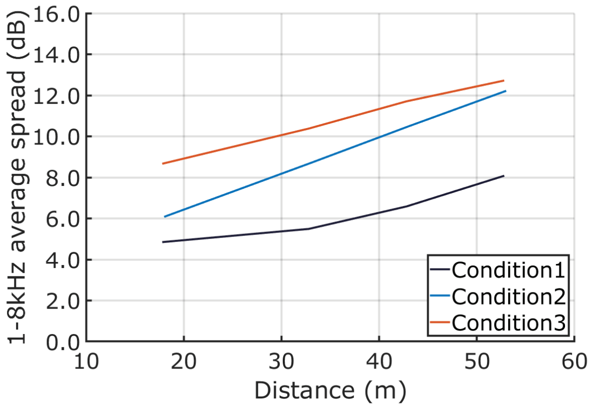
Influence of wind conditions

The wind speed or variations of wind over time have a direct impact on the average spread. This can be observed on data captured under different wind conditions.

[1]- Optimization done during the design in Soundvision and adapted during the show using Autoclimate.

Wind speed was measured by two weather stations and averaged to be more representative of the ambient conditions (smoothing of local variations).

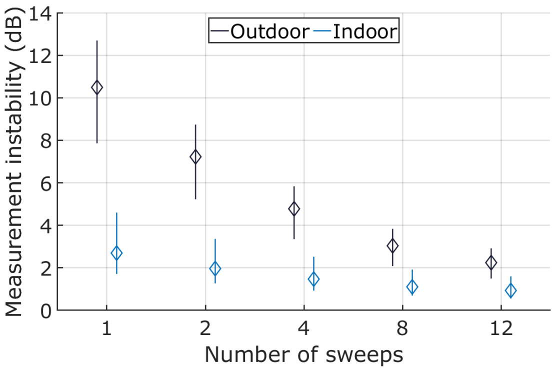




The mean value of wind speed (x) indicates how strong the wind was during the measurement session. Vertical bars indicate the difference between the 25th and 75th percentile values which reveal the variability of wind speed during this period. In Condition 1, there was no wind. This leads to relatively low spread values in comparison to Condition 2 or 3. The wind was less constant in Condition 3 than in Condition 2, which explains the higher average spread observed.

Influence of number of sweeps

A measurement is the result of multiple sweeps captured and combined by averaging techniques. When relying on insufficient number of sweeps, the measured frequency response can vary significantly from one time to another.



Example of measurement instability obtained outdoor (L-Acoustics, wind Condition 2 described above) and indoor (AccorHotels Arena, Paris, France), at 40m with 1 to 12 sweeps.

Repeating sweeps is the only solution to make the measurement more stable over time. Nevertheless, there is only limited benefit of using more than **8 sweeps outdoor**, and **4 sweeps indoor** when looking at the measurement instability values (see Stability of responses).

At 40m, outdoor measurements obtained with one sweep would typically vary by 10dB at high frequencies when realized at a few minutes' intervals. Using 8 sweeps, the measurement response would vary by 3dB only. Vertical bars indicate the difference between the 25th and 75th percentile values across frequencies.

Note: beyond 60m, outdoor measurement instability remains high no matter the number of sweeps (≈3-5dB with 8 sweeps at 80m)

GLOSSARY

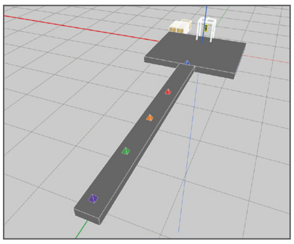
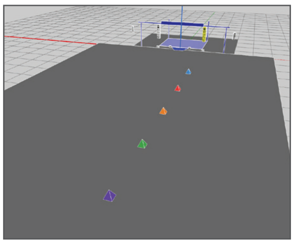
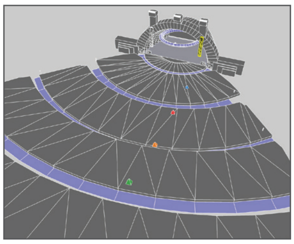
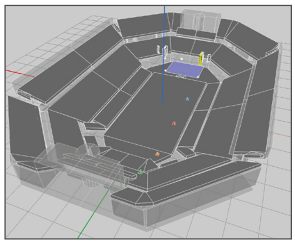
EQ / Equalization: Tool or process aimed at electronically adjusting the frequency response of an audio system.

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

High frequencies: Frequencies above 1 kHz when the hearing frequency range is split into two (low/high).

ANNEX 1: MEASUREMENTS SETUP

Measurements were performed both indoor and outdoor to assess the stability of frequency responses in different environments. Microphones were placed at regular distances, between 20m and 120m depending on the loudspeaker system coverage. A large dataset was created by measuring multiple series of 50 sweeps in sync with atmospheric data (temperature, humidity, wind speed and direction).

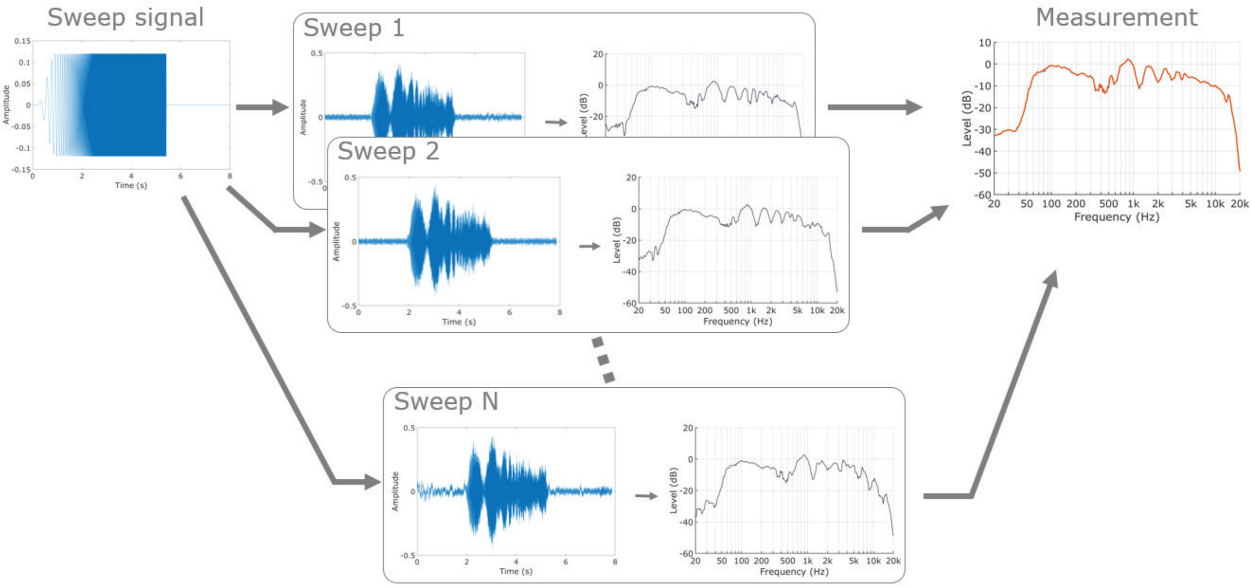





L-Acoustics R&D facilites, Paris, France	Solidays open-air festival, Paris, France	Hollywood Bowl, Los Angeles, CA, USA	AccorHotels Arena, Paris, France (indoor)
8 KARA	4 K1-SB + 12 K1 + 2 K2 (down)	4 K1-SB + 16 K1 + 4 K2 (down)	12 K1 + 4 K2 (down)

ANNEX 2: STABILITY OF RESPONSES

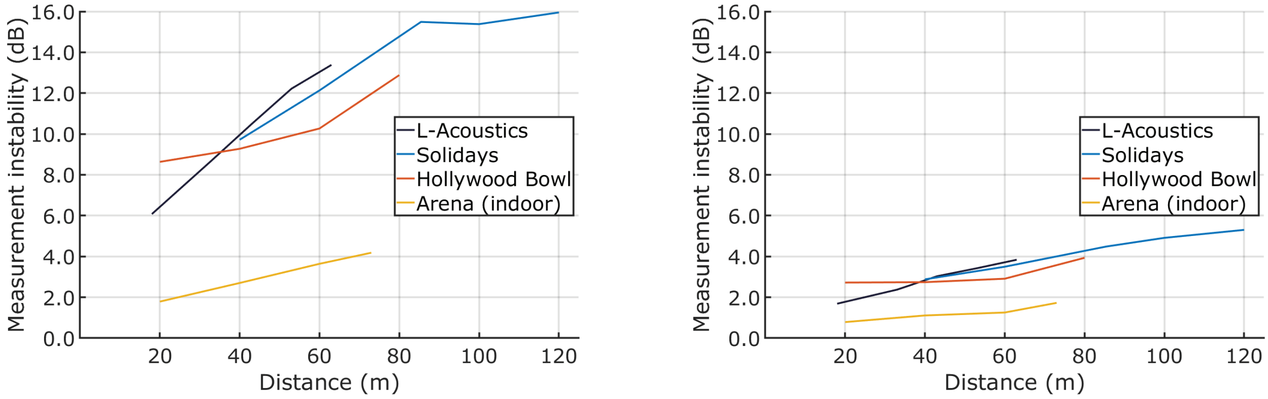
The stability of measured responses can be assessed through two aspects:

- How different are repeated sweeps?
  This is estimated by the <u>average spread</u> of responses.
- How stable is a measurement over time?
  This is estimated by the <u>measurement instability</u>.



The **average spread** of responses is estimated as follows: for each frequency, the range (max – min) of smoothed frequency responses (1/6th octave) is calculated in dB. The “average” spread corresponds to the median value of this range across frequencies, either banded (1kHz, 2kHz, 4kHz, 8kHz) or wide band (1-8kHz octave bands).

Measurements are combinations of N=1, 2, 4, 8, or 12 consecutive sweeps (average in dB). The **measurement instability** is calculated as the spread of measurements performed at a few minutes' intervals. Instability values are estimated wide band (1-8kHz octave bands).

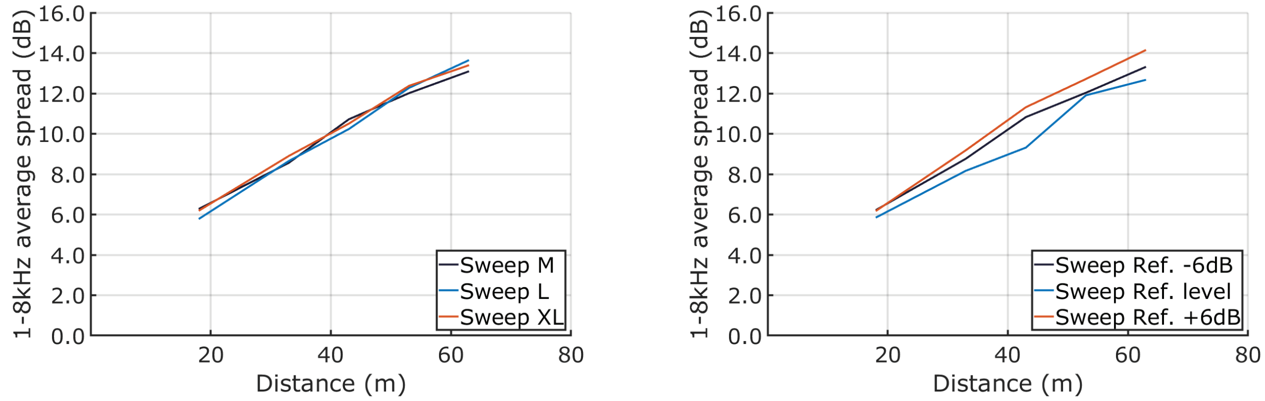


Measurement instability (median values) for 1 sweep (left) or 8 sweeps (right).

ANNEX 3: INFLUENCE OF SWEEP DURATION AND SWEEP GAIN

Series of 50 sweeps were repeated in the same environment (L-Acoustics R&D facilities) using three sweep durations (M = 1.36s, L = 2.73s, XL = 5.46s), and three sweep gains (Reference level, Ref. -6dB, Ref. +6dB). The nine series resulting from the combination of sweep duration and gain were measured two times (100 sweeps per condition, 900 sweeps in total).

The gain of the system was set to ensure exploitable data even in the worst-case scenario in terms of Signal-to-Noise Ratio. According to this method the level was set so that, at the furthest microphone location (63m) the Signal-to-Noise Ratio measured with the shortest sweep duration (M) and the lowest sweep gain (Ref. -6dB) is over 20dB.



Effect of sweep duration (left) or sweep gain (right) on average spread.

Data were averaged over the three gains conditions to study the influence of sweep duration (e.g. Sweep M is the average of all the Sweep M played at Reference level, Ref. +6dB and Ref. -6dB). Similarly, data were averaged over three durations conditions to study the influence of sweep gain. Results indicate that modification of sweep duration or sweep gain has no major impact on the average spread nor on the measurement instability.