**Source:** **Nokia**

**Title:** **On raw and compensated microphone signal requirements**

**Document for: Discussion & Agreement**

**Agenda Item: 7.6 – DaCAS**

# 1. Introduction

To obtain well performing spatial audio capture algorithm in any device, performance of raw and compensated microphones of the device is crucial. In this document, we discuss and propose requirements and recommendations for integrated microphones in terms of their raw performance. In addition, important aspects on compensated microphone signal assessment are presented.

# 2. Requirements on raw microphone signals

## For successful development of spatial capture algorithm for a raw microphone signals of target device, certain requirements on the raw microphone signals and characteristics should be expected. In the following sections, considerations about raw, frequency response, as well as performance in terms of Signal-to-noise -ratio, sensitivity and directivity properties and discussed. In addition, some remarks on how to obtain these features are presented.

## 2.1 Characteristics

Raw microphone characteristics of the target devices should be well understood in order to develop high quality spatial audio capture solutions for target devices. Important characteristics for ensuring feasible performance are raw frequency response, as well as performance in terms of Signal-to-noise -ratio, sensitivity, and directivity properties of integrated microphones.

Typically, microphone integration is influenced by a different design constraint, e.g., microphone placement, placement of other components, required protection, etc. In addition, some acoustic filtering effect including resonance is obtained for all microphone integrations. Favorable characteristics for all integrated microphones are high resonance frequencies, and small resonance magnitude with low Q factor. In addition, to ensure feasible frequency response compensation (e.g., equalization), it is desired to have somewhat flat response for the frequency regions outside resonances, i.e., all frequencies are captured (within designed limits), and no high-pass or other strong filtering effect is present.

Furthermore, Signal-to-Noise -Ratio (SNR) describes the ratio between desired signal and the device’s noise floor. It has a direct relation to achieved capture quality; thus, higher SNR is desired. Modern MEMS microphones typically can achieve easily over 60 dB SNR, which is also seen as a sufficient target level for DaCAS target devices.

In addition, microphones have certain sensitivity characteristics. Typically, upper and lower limits (highest manageable SPL level and lowest captured SPL level) can be determined for the characterized microphone. For DaCAS target devices, it is not seen as a necessary to consider lower sensitivity characteristics. However, to ensure sufficient headroom, the integrated microphone signal level should be below -25 dBFS, when device is exposed to the 1 kHz sine signal at 94 dB SPL level.

In terms of directivity of the integrated microphones, omnidirectional characteristics are preferred. Typically, other directivity patterns require additional care and specific solutions, in order to obtain sufficient spatial capture quality.

Thus, based on the discussion above, following requirements and recommendations for raw microphone signal characteristics are proposed:

**Following text is proposed to be agreed for further offline editing:**

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Raw microphone input for DaCAS solution shall comply with the requirements specified in Table 1.

**Table 1 Raw microphone signal requirements**

|  |  |
| --- | --- |
| **Feature** | **Requirement** |
| Raw frequency response (excluding resonances) | Minimum captured frequency (-3dB point) shall be below 100 Hz  Frequency response above the minimum frequency and below the resonances should be as flat as possible. |
| Resonances | Recommended to be above 10 kHz.  Should be above 8 kHz. |
| SNR | Should be over 60 dB, recommended to be over 65 dB |
| Sensitivity | Level should be below -25 dBFS with 1 kHz @ 94 dB SPL |
| Directivity | Recommended to have omnidirectional characteristics. Other directivity patterns are not generally excluded.  Microphone directivity characteristics shall be documented clearly. |

Note: It is expected that all the raw integrated microphones comply with the above requirements. In addition, it is favorable to have as similar characteristics as possible for all raw integrated microphones.

Compensated microphone input for DaCAS solution shall comply with the requirements specified in Table 2.

**Table 2 Compensated microphone signal requirements**

|  |  |
| --- | --- |
| **Feature** | **Requirement** |
| Compensated frequency response | Compensated frequency response should be considered in the context of isotropic equalization target.  Should consider criteria for frequency response differences between integrated microphones and their compensated frequency responses.  Shall be within mask: [TBD] |

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It is seen that all integrated microphones should comply with the above requirements. In addition, it is favorable to have as similar characteristics as possible for all integrated microphones, as typically the lowest performing component will limit the achieved quality and accuracy. For example, as the resonances frequencies of the microphones typically limit the accuracy of spatial analysis, the lowest obtained resonance frequency (of any microphone) may limit the overall performance. However, limiting target devices to comprise, .e.g, only the same microphones is not seen as a mandatory.

In addition, the source thinks that there is no need to limit proponents for proposing all kinds of target devices, as long as there is a clear understanding on the limiting factors for achieved capture quality. Thus, above requirements are merely seen as guidelines for defining a well performing target device which is feasible for high quality spatial audio capture solution development. However, we think that proposed minimum SNR should be agreed, as well as rough requirements for raw frequency response in terms of lowest captured frequency.

## 2.2 Obtaining the characteristics

Many of the above presented details can be typically found from the datasheet of the applied microphone. However, some of the details should be assessed from the integrated microphone.

Raw frequency response for each integrated microphone can be measured in an anechoic chamber as a function of source direction. Such measurement for 3D direction can be done, e.g., using a turntable and multiple elevated sound sources. Further details for such measurement are presented in [1].

Recording scenario for obtaining SNR of the integrated microphone is proposed in the [1]. For obtaining the SNR based on the recording, following equation is applied:

where is the A weighted level of the recorded microphone noise floor, and is the recorded microphone level with 1 kHz sine signal with acoustic level of 94 dB SPL at the microphone position. Both values are in linear scale.

Sensitivity and the presence of required headroom may be evaluated from the same SNR measurement by assessing the level of the recorded 1kHz sine signal.

# 3. Requirements on compensated microphone signals

Microphone signal compensation would be an attractive target to simplify IVAS technology support by removing unnecessary product specific technical complexities related to microphone hardware integration to product mechanics. Device manufacturers have access to all necessary information and access to device hardware to provide favorable signal conditioning by compensating unwanted frequency response distortions to agreed specification. Information sharing of compensated microphone responses may also be less sensitive to manufacturers, because microphone responses compensated or equalized to commonly agreed target response or mask would not include the same amount information about HW design details compared to raw microphone signals. Thus, the challenge would be how to define and agree on common target response, or frequency response mask, characterizing frequency response for each microphone integrated into product mechanics.

However, when microphones are integrated into product mechanics the measured raw microphone signal and frequency response becomes non-isotropic, which leads to situation where, depending on where the microphone audio inlet is located in the device mechanics, the measured signal and frequency responses are function of sound source direction (DOA). This directional dependency complicates the definition of target response of mask for compensated microphone signals.

Compared to frequency response masks in current specification [2], it would be a major complication to specify a simple measurement procedure for arbitrary product mechanics, if the measurement setup would be dependent of product shape and positioning of each microphone inlet. Therefore, we propose that microphone signal compensation should be considered in the context of isotropic equalization target where each microphone would be characterized independent of sound source direction and microphone inlet placement in device mechanics.

## 3.1 Compensated frequency response

Definition of non-isotropic compensated frequency response requires a definition on how the frequency response is measured. Currently defined frequency response masks, such as mask for Handset devices for Super-wideband [3] have +/- 4dB variations, this level of variation may limit the performance of microphone arrays and multi-microphone technologies. Therefore, there may be a need to consider criteria for frequency response differences between multiple integrated microphones integrated into a device and their compensated frequency responses.

# 4. Summary

In this contribution requirements and recommendations for the raw microphone signals are presented and proposed. All the proponents are proposed to follow and consider the proposed requirements and recommendations in Table 1. Regarding many features, the source considers that there is no reason to limit the technical capabilities of the proposed target devices (e.g., in terms of microphone directivity), as long as the proponents have a clear understanding on related limitations regarding possible example solutions. Thus, in many cases, these proposals can be seen as guidelines and recommended best practices.

Furthermore, we propose that the microphone signal compensation should be considered in the context of isotropic equalization target. In addition, criteria of frequency response differences between multiple integrated microphones should be considered.

# References

[1] S4-250593: “On DaCAS recording scenarios”, Nokia

[2] 3GPP TS 26.131: “Terminal acoustic characteristics for telephony; Requirements” version 18.1.0 Release 18