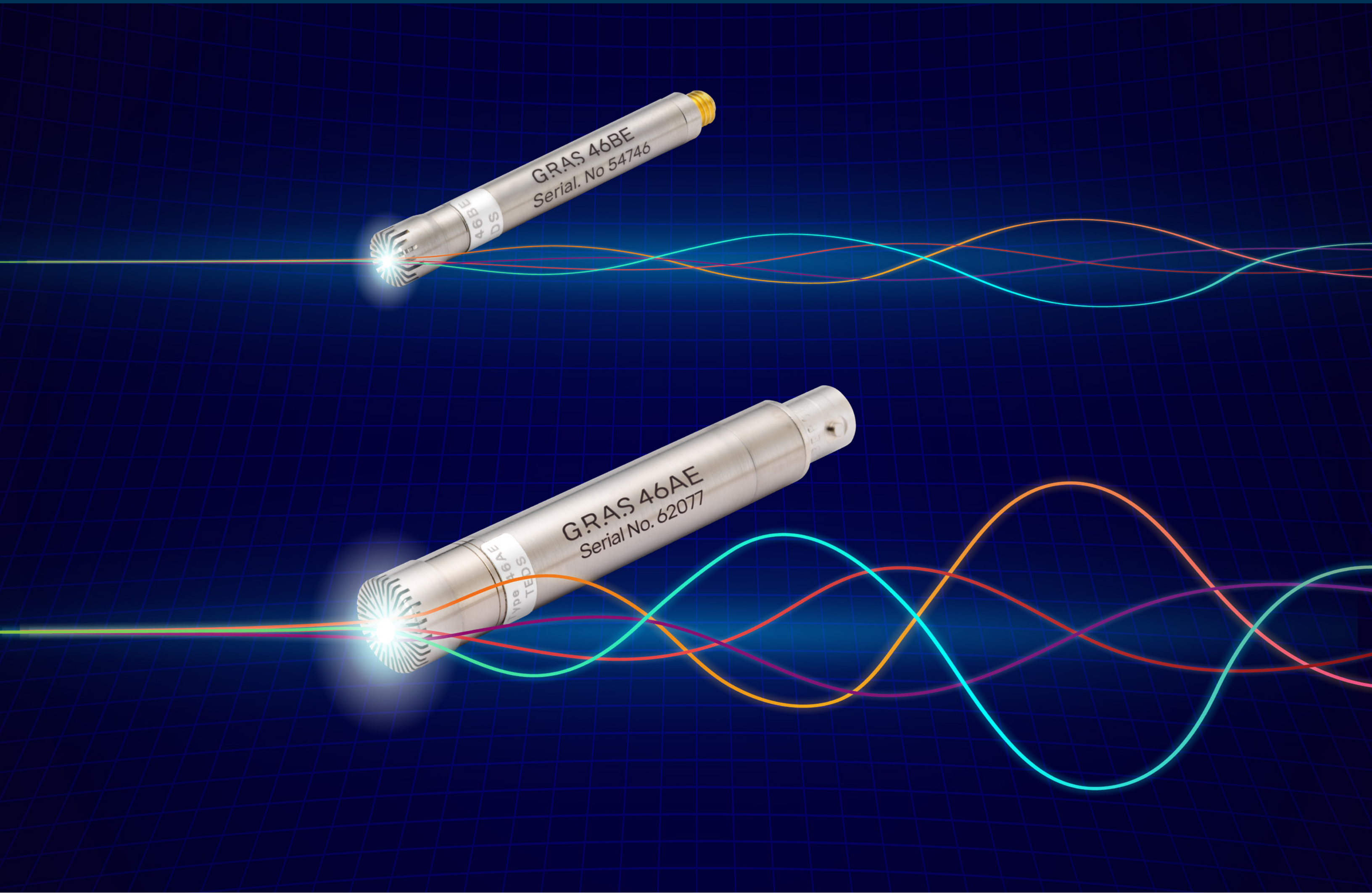
GRAS Sound & Vibration



On the advantages of using ¼″ measurement microphones to reduce uncertainty

GRAS Sound & Vibration
Whitepaper // By Dr Rémi Guastavino and Kim Boldt

WHITEPAPER

Introduction

The observer effect is the disturbance of an observed system by the very act of observation. A simple example would be placing a warm thermometer in cold water. The interaction between the thermometer and the water will cause a change in both, so that the thermometer sensor will change temperature and display the value, but that value will be ever-so-slightly higher than the water temperature prior to the introduction of the thermometer. As in the thermometer example, for many physical measurements, the effects of observation are often negligible; however, there are measurement scenarios where they are very apparent.

This whitepaper addresses elements of size-dependent characteristics of measurement microphones, including:

- How the size of an object in physical space can affect a measurement.
- How microphone diaphragm reacts to incoming signals based on diaphragm size and angles of incidence.

Microphone size and design

Measurement microphones are highly specialized and fine-tuned devices designed for sensing minute dynamic variations in the ambient pressure. And they are designed to operate in a particular sound field and purpose. Therefore, it is important to use the correct tool for the job—pressure microphone in a pressure field, free-field microphone in a free field, etc. For more information on matching microphones to sound fields, see [1].

But along with using the correct tool is using the tool correctly. It is important to remember that measurement microphones use a very thin (only a few micrometers thick) metal foil as a diaphragm to be able to sense minute variations ambient pressure. The thinness of the diaphragm allows it to deform even when the excitation is extremely small, making the very detection of pressure variation possible even at low sound pressure levels.

The diaphragm is, of course, quite fragile, so an errant sharp object hitting the diaphragm could destroy the microphone's sensing capability. Microphones are therefore delivered with a protection grid. For measurement microphones, particularly those that are ½″ and larger, the grids are acoustically transparent at low frequencies. However, at higher frequencies and on smaller diameter microphones, protection grids act as resonators and have a noticeable influence on the frequency response.

In high-frequency measurements, where ¼″ and ⅛″ microphones are the preferred microphones, the resonance issue begins around 20 kHz. Here the wavelength is so small that the space between the protection grid openings can cause resonance. This problem becomes more pronounced the smaller the microphone diameter is.

Therefore, ¼″ and ⅛″ microphones are optimized to be used without the protection grid in order to obtain accurate high-frequency data. So don't forget to remove the protection grid when measuring.

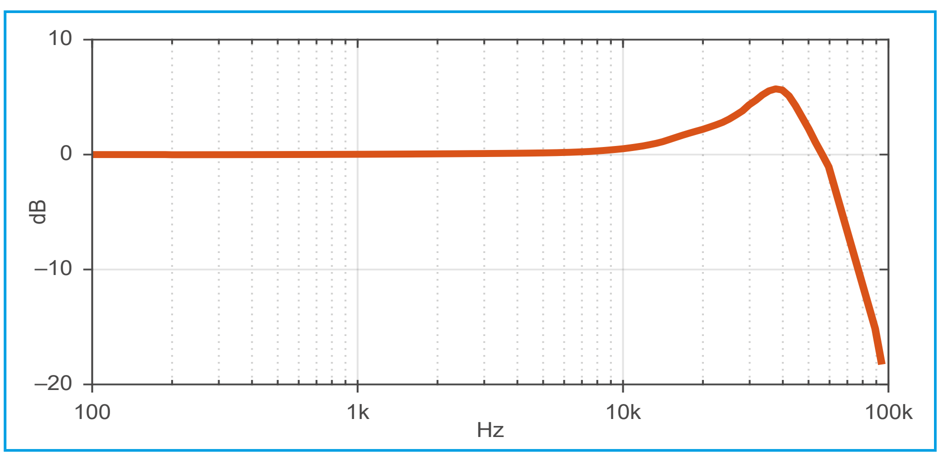


FIGURE 1.
Using ¼″ or ⅛″ microphones with the protection grid will impact the microphone frequency range as shown—in this case a GRAS ¼″ microphone. The resonance frequency and amplitude will depend on the protection grid.

Free field

In acoustic measurements, any physical object in the acoustic environment will disturb the propagation of waves, and in some cases that effect is negligible. However, if the wavelength is not an order of magnitude larger than the microphone diameter, the microphone in a sound field will significantly influence the local sound pressure (Fig. 2).

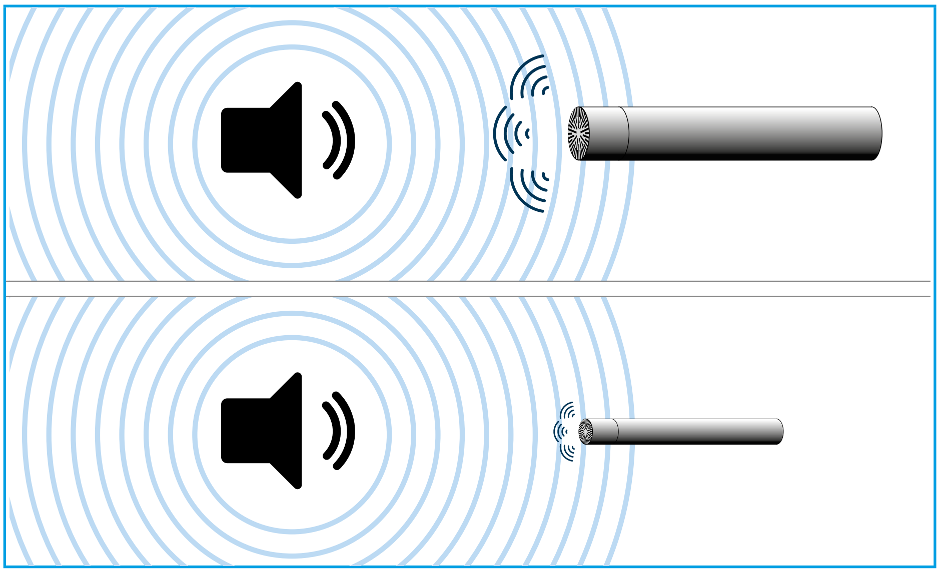


FIGURE 2.
Representation of the pressure build magnitude vs microphone size.

To compensate for this effect, free-field microphones have been developed. The frequency response of a free-field microphone corrects for the effect of its own presence in the sound field (Fig. 3).

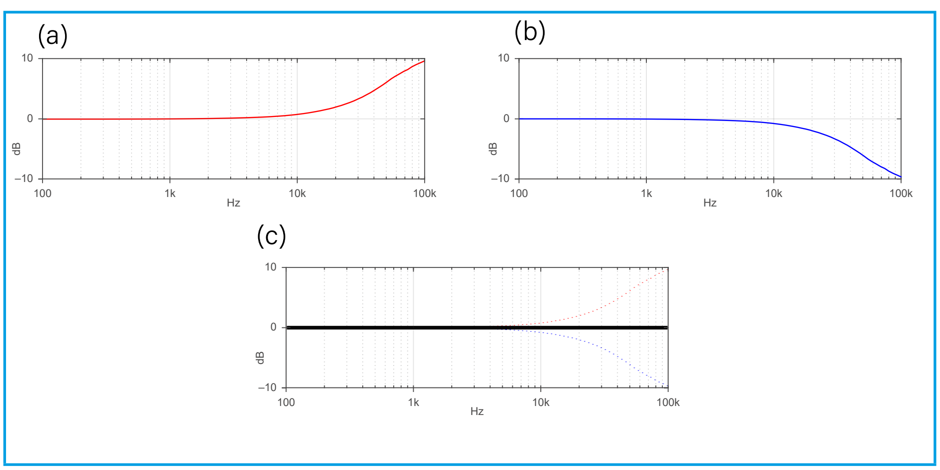


FIGURE 3.
Effect of the pressure build up at a ½" free-field microphone membrane (a), correction (b) and resulting data (c).

However, this correction is only valid when the microphone is pointing directly to the sound source. This means that it is not accurate when the sound is coming from any other direction. Therefore, free-field microphones are optimized for use in reflection-free environments like anechoic chambers or when using a time-selective algorithm that artificially removes reflections, so as to only include direct sound waves.

The pressure build up at the microphone diaphragm is directly proportional to the ratio between the diaphragm size and the sound wavelength. This is why the pressure build up is less important for smaller microphones at any given frequency. For example, as can be seen in Figure 4, the pressure build up for a ½" microphone at 20 kHz is in the order of magnitude of 10 dB; whereas, the pressure build up will only be approximately 4 dB for a ¼" microphone. The deviation can be considerable.

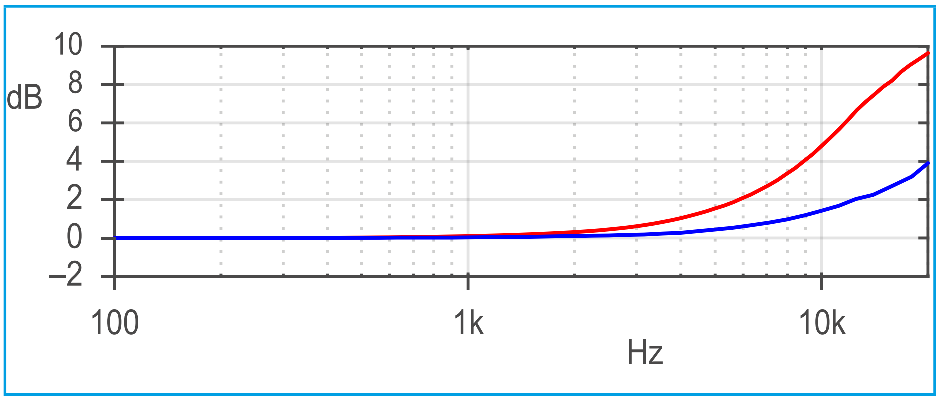


FIGURE 4.
Frequency-dependent pressure build up for ¼" (blue) and a ½" (red) microphones at 0° incidence.

It is important to remember that even though it is possible to compensate for the pressure build-up effect, greater corrections also incur greater uncertainty. This means that, to minimize measurement uncertainty, it is often good practice to use small microphones, specifically, the use of a ¼" is always to be preferred when the noise floor of the sensor is not an issue. The diaphragms of smaller microphones are less sensitive to pressure variations than microphones with larger diaphragms, so they have a higher noise floor.

Angles of incidence

The angle of incidence is the angle between the surface of the diaphragm at its central point and the direction of a sound wave approaching the microphone. As noted earlier, free-field microphones are optimized for a sound wave approaching at a 0° angle of incidence to the surface of the diaphragm (or a wave approaching from a direction in line with the microphone's axes of symmetry).

It is also important to note that because of the axial symmetry of a microphone, we only need to know polar angle θ corrections between 0° and 180°, corrections will be unchanged for different azimuthal angle ϕ (see fig. 5)

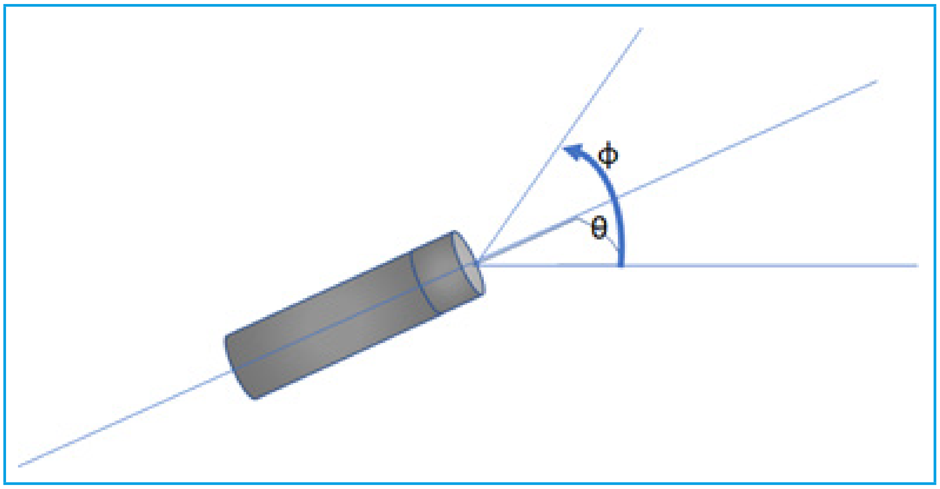


FIGURE 5.
Axial symetry of a measurement microphone.

In a real-life measurement scenarios, sound waves will come from different directions (Fig. 6) and are not alone.

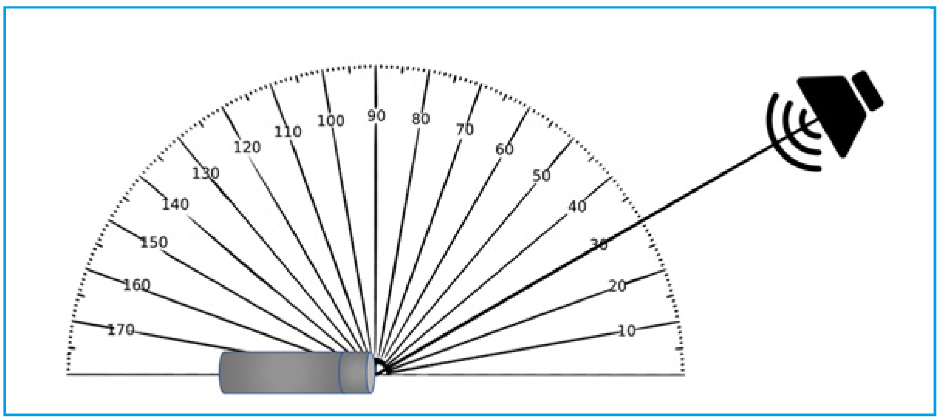


FIGURE 6.
Angle of incidence relative to microphone orientation.

The effect of the microphone size at different angles is described in Figure 7. The graphs depict the free-field response of a microphone relative to the 0° response in 30° steps. Note that the microphone is physically symmetrical, the response measured at 30° is the exact same response as at -30°.

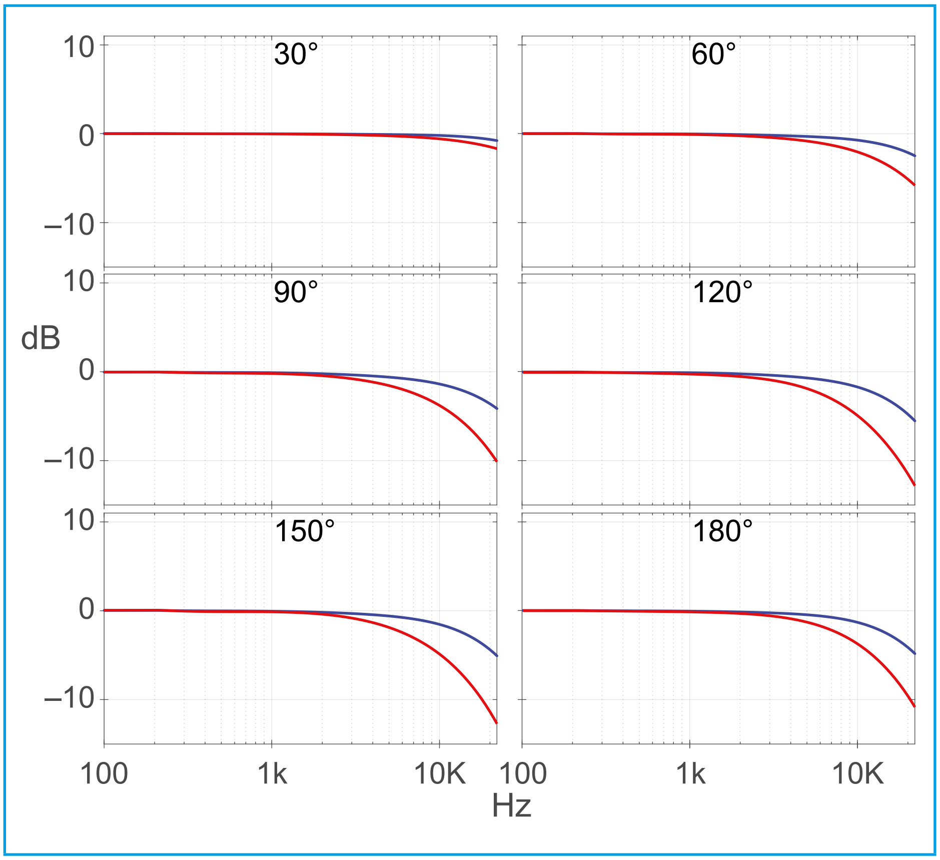


FIGURE 7.
Free-field response curves for ¼″ (blue) and ½″ (red) microphones relative to the 0° response in 30° steps.

Angle of incidence measurements are difficult to perform due to room reflections, and there is no perfectly anechoic chamber. Therefore, special care must be used to remove reflections from the room using an advanced reflection removing algorithm. Hand-in-hand with the observer effect, the room is not the only problem. Items associated with the microphone can also influence the measurement. Reflections from the microphone holder must also be avoided, and even hanging the microphone with thin sewing thread is acoustically visible above 20 KHz.

The measurements show that at 30° and 20 kHz, a ½″ microphone under-represents the sound pressure by 1.5 dB, compared to around 0.6 dB for a ¼″ microphone. The worst case is at 120°, where a ½″ microphone is under-representing the sound pressure by almost 12 dB (that's around 25% of the original pressure) while a ¼″ microphone only under-represents the sound pressure by less than 5 dB.

Diffuse-field correction

When measuring in a room where sound waves are coming from different directions (typically in cabin noise or architectural acoustics measurements), it is good practice to use the diffuse-field correction. The diffuse-field correction gives the best compromise to achieve a flat response in the theoretical situation where the sound waves are arriving simultaneously from all directions with equal probability and level.

Because this never happens in real-life situations and because we cannot yet distinguish the directions of the sound wave using a microphone with only one membrane, the diffuse-field correction will tend to underestimate sound waves coming from certain direction and overestimate other.

The only way to avoid this is to have a microphone that is so small than it became acoustically invisible and does not disturb the sound field. This is a not an existing solution right now.

To minimize effects due to microphone size, using a ¼″ microphone is recommended. As shown in Figure 7, the influence of the angles of incidence are much smaller on a quarter inch and the under- and over-representation due to angles of incidence will be an order of magnitude smaller than on a ½″ microphone.

Conclusion

When measuring to gain useful data in real-world conditions where there are many reflections and disturbances, such as in-cabin, the physical advantages of a ¼″ microphone can greatly increase accuracy and simplify post-processing data, requiring fewer estimations for corrections. And adding to the benefit of the more accurate sound pressure level data, the smaller size of the microphone itself will reduce reflections and disturbances, reducing measurement errors and providing greater certainty.

References

1. R. Santiago. How to Match a Measurement Microphone to a Sound Field. GRAS, 2021.