What are the different types of microphones available depending on the type of soundfield?

Choosing the right measurement microphone is essential for obtaining useful measurement data. The different types of microphones are designed for different types of sound fields. Understanding the differences between the microphones can help the user to select the right microphone and avoid possible measurement errors.

Typically, the sound field is complex and therefore it is important to understand the relationship between the microphone and the acoustic surroundings. A sound field with many reflections and standing waves can be a challenge. Whether it is free-field, diffuse-field or something in between, a reasonable choice of the measurement microphone makes post-processing and analysis of the data much easier.

Determining what type of sound field is present is also important for choosing the right microphone for the measurement and getting reliable results. The three different ideal sound fields are described as follows:

A. Pressure field

A pressure field is defined as the sound field on a surface or a small closed chamber, where the phase and magnitude are the same throughout. This could be the inside of a wind tunnel, small cavities, boundary layers or acoustic couplers.

B. Free field

A free field is defined as a sound field without any objects that can introduce reflections. So the only sound arriving to a microphone/listener in this sound field is the direct sound without the influence of any reflections. Assuming a single monopole sound source, the sound field can be approximated to simple plane waves radiated in a well-defined direction. A loudspeaker in an anechoic chamber can be considered a free-field situation in a limited frequency range determined by the size of the chamber.

C. Diffuse field

A diffuse field, or random incidence field, has sound arriving with equal probability and level from all directions. It can be a room with many objects causing reflections in many directions (see standard IEC 61183 Random Incidence and diffuse field calibration of sound level meters). In practice, reverberant chambers for acoustic testing try to replicate a diffuse field within a limited frequency range.

Given the 3 above mentioned sound fields, it is possible to define 3 main different types of measurement microphones available in the market:

Figure 1. Left: Pressure microphone mounted in an enclosure with an angle of zero degree relative to source. Middle: Free-field microphone in an angle of zero deg relative to source. Right: Random incidence microphone with illustration of sound coming from all directions

A. Pressure microphones

A pressure microphone is designed to measure the actual sound pressure on the surface of the diaphragm of the microphone. This means that if the microphone is somehow disturbing the sound field and causing a diffraction effect, the microphone will measure that and the measurement results will be affected. Therefore, pressure microphones are typically mounted on a boundary (e.g. a wall) or as a part of a closed volume as an ear simulator. Thus, it measures the sound pressure on the boundary itself (Figure 1 Left).

B. Free-field microphones

As explained before, placing an object in a sound field will cause some local disturbance to the sound field. The free-field microphone (Figure 1 Middle) is designed in such a way that it corrects for its presence in the sound field and measures the sound pressure as if the microphone was not present.

Free-field microphones are designed to measure the sound pressure as it was before the microphone was introduced to the sound field, therefore compensating for its disturbances caused to the sound field. Ideally, the presence of the microphone should not affect the measurement.
The free-field microphone is designed so that the sensitivity of the microphone decreases with the same amount as the acoustical pressure increases in front of the diaphragm (due to the diffraction effect). This is obtained by increasing the internal acoustical damping in the microphone cartridge. The result is an output from the microphone, which is proportional to the sound pressure, as it existed before the microphone was introduced into the sound field.
In other words, if we know exactly how the microphone is disturbing the sound field, then we can design a microphone with a frequency response that compensates for the disturbance it is creating. Blue curve in Figure 2 shows the typical pressure build up that occurs when pointing a pressure microphone directly to a sound source (due to diffraction effects). The black curve shows the pressure response of a free-field microphone. The pressure response of the free-field microphone is dampened in order to compensate for the pressure build-up at high frequencies. Therefore, if we use a free-field microphone in a free-field (e.g. anechoic chamber) and point the microphone directly to the sound source (0-degree incidence), the microphone will now have a flat frequency response (red curve).

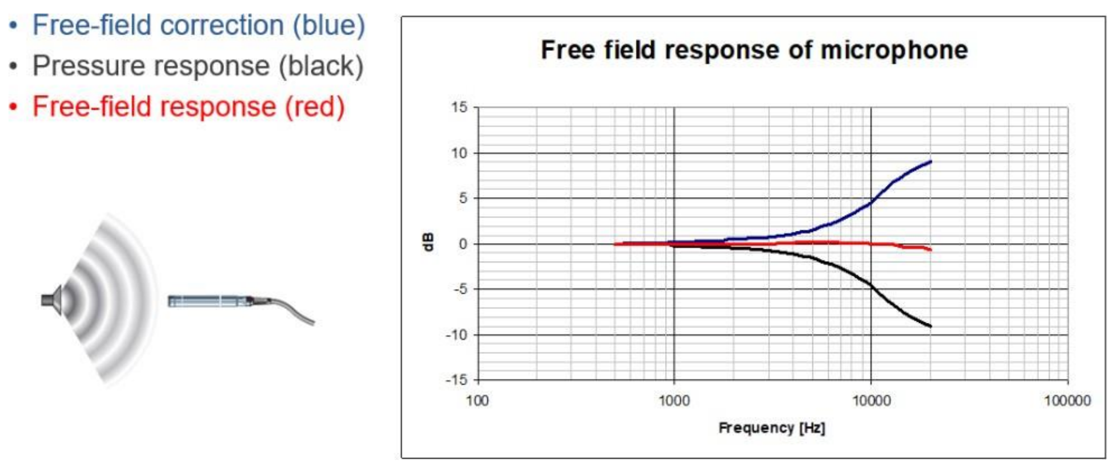

Figure 2. Typical pressure response, free-field correction and final free-field response of a ½" free-field measurement microphone.

It is very important to point out that this compensation will only work in a free-field environment at 0-degree incidence from a sound source.

Free-field microphones have been stablished as the standard microphone for acoustic measurements in many applications, even when we are not working in an ideal free-field situation.

C. Random-incidence microphones (also known as diffuse-field microphones)

In a random incidence sound field, where the sound comes from all directions with equal level, a random-incidence microphone should be used. This can be in a reverberation chamber or spaces with many reflecting surfaces (see Figure 1 Right).