INSTRUMENTATION CORNER

Microphone selection for measuring in reverberant spaces, and electrical corrections networks for diffuse-field response in a sound level meter

The current Standards for sound level meters allow both free and diffuse field (random incidence) responses; however, the most common measurement requirements are for free field responses. As a result, most sound level meters in service are fitted with free field microphones.

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There are applications that require diffuse field levels to be measured, such as sound insulation measurements in buildings and sound power in reverberant rooms/spaces. To avoid the necessity of having a different microphone capsule for these measurements many sound level meter manufacturers fit electrical correction networks that will convert the acoustic free field response to an effective diffuse field response.

In the United Kingdom the accreditation authority, UKAS, are now requiring[1] these correction networks to be included in the standard accredited periodic verification procedure[2]. The objective of this technical note is to give an understanding of the basis of such correction networks and the impact they will have on the uncertainty of the result.

Firstly, a quick recap on microphone types:

- A free field microphone is designed essentially to measure the sound pressure as it was before the microphone was introduced into the sound field.
- A pressure microphone is for measuring the actual sound pressure on the surface of the microphone's diaphragm.
- A random incidence microphone is for measuring in sound fields, where the sound comes from many directions e.g. when measuring in a reverberation chamber or in other highly reflecting surroundings.

The basic WSM2F[3] microphone used in class 1 sound level meters is a pressure device that has been engineered to provide a free field response. So, starting with a flat pressure response there will be an increasing response with frequency as the wavelength approaches the diameter of the microphone capsule due to the reflections of the incident pressure wave from the microphone itself. As most meters have half-inch microphones these effects will start to be seen above 1 kHz and extend to around 10 dB at 20k Hz (Figure 2). By careful design changes to the diaphragm mass, compliance, tension and damping the basic pressure response may be attenuated in the exact opposite direction to this unwanted pressure build up, resulting in a flat free field response, namely the sound field that was present before the introduction of the measurement microphone to the sound field.5

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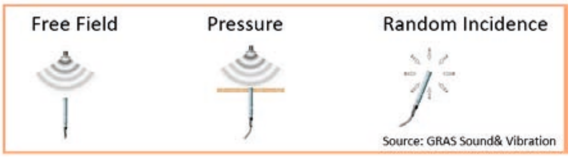
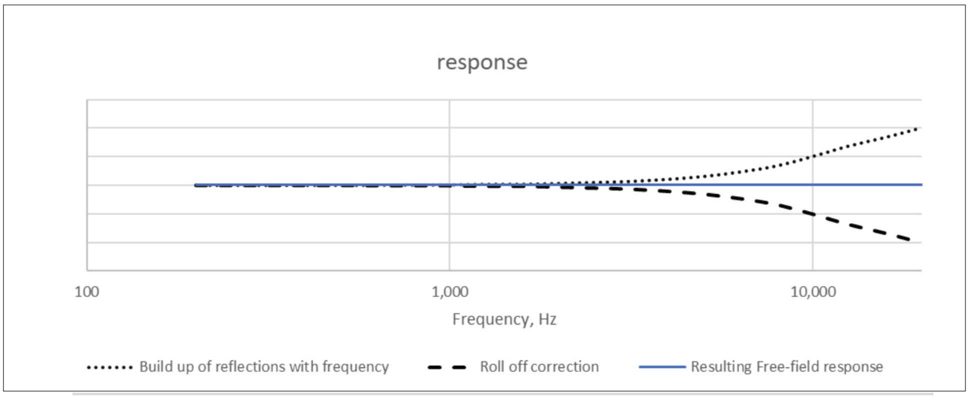


Above: Figure 1: Microphone types

Below: Figure 2: Pressure microphone engineered to have free field response



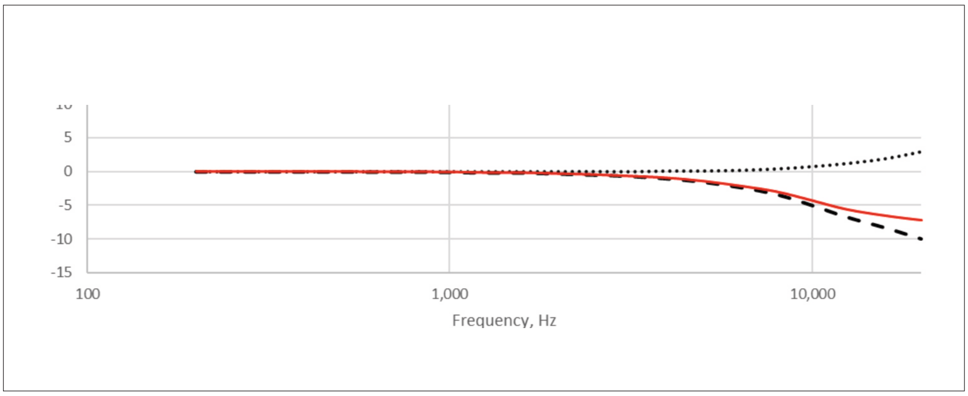
1 LAB23 Edition 3 January 2023
2 BS EN IEC 61672-3 Periodic verification of sound level meters for legal metrology applications
3 BS EN ISO 61094 Laboratory and Working Standard Microphones

The build-up of the reflective and diffracted field around the microphone is effectively cancelled by the engineered roll off in the microphones pressure response.

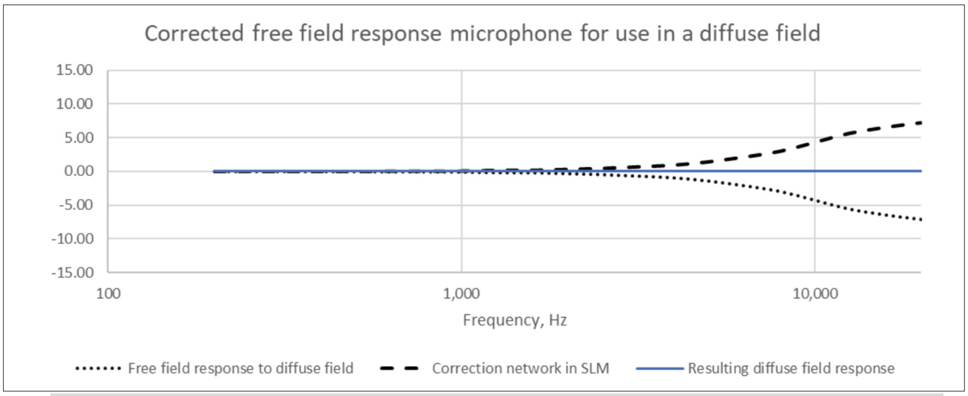
If the free field microphone is then used in a diffuse field there will then be a lower reflective build-up of sound field around the microphone diaphragm; and hence the engineered roll off will be too large to exactly cancel this out, resulting in a non-linear diffuse field response as can be seen in Figure 3. The resulting error at high frequencies will be in the order of 7 to 8 dB at 20k Hz. The engineered roll off that gave the free field response is inherent to the design of the microphone capsule and cannot be changed. The answer is therefore, to build a correction network into the electronic circuits of the sound level meter. This will have to be designed to compensate for the difference between the pressure to free field response of the microphone and the smaller amount of reflective build up in a diffuse field (Figure 4). The correction will therefore only be true for the model of microphone fitted to the sound level meter when it was new and, of course, it would be a nominal correction based on the production spread found in both the microphone capsule and the filter tolerances in the sound level meter.

This is a simplified example to show the principle of the correction network, in practice there are other factors that the manufacturer needs to consider when designing the correction network. The build up in front of the microphone diaphragm is primarily due to the reflection from the microphone diaphragm as the incident sound wavelength becomes shorter than the size of the diaphragm it is incident upon. But there are other components such as diffraction around the microphone as well as reflections from the body of the sound level meter itself. There are other front-end accessories that also need to be considered such as windscreens and weather protection in the design of the filter response required.

Should you use an alternative microphone it is possible to look at the manufacturer's data for it to determine the nominal pressure to free and diffuse corrections and, from these, determine the correction that would be needed. We have done this for three different WSM2F microphones and shown the result in Figure 5 against the standard manufacturers (Norsonic) correction. The use of electrical correction networks is a compromise, and it will not be as good as a true diffuse field microphone. The addition of up to 10 dB of gain at some frequencies into the measurement chain will have the effect of moving the measurement nearer to the overload level and at the other P58



Above:
Figure 3: Use of free field microphone in diffuse field results in errors



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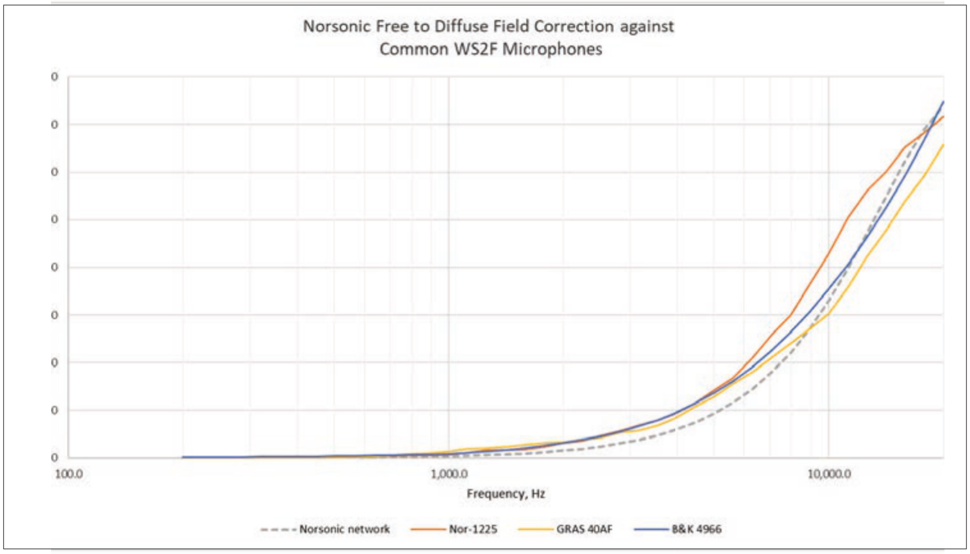

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Figure 5: Comparison of actual correction network from nominated and equivalent WSM2F microphones

end of the dynamic range it will increase the self-noise. There will also be some additional components to consider in the uncertainty budget, these are mostly related to the normal spread of performance of the microphones in respect of their polar response that controls the magnitude of the diffuse and free field responses. Of the microphones we have looked at for this exercise, they were all around 0.1dB at low frequencies going up to 0.5 to 0.9 dB at high frequencies.

One of the primary applications that is driving this investigation is building acoustics and it is worthwhile considering the wider aspects of such a measurement. In building acoustics, we compare the difference between the source and receiving room levels. So if the same measurement kit is used for both measurements, the difference between the two rooms would, in general, be the same with or without the diffuse field filter in circuit. This is not the case with impact measurements where only receiving room measurements are made. Sound insulation measurements are usually only taken up to 3,150Hz/5kHz where the effects are less significant. Other applications such as sound power testing in reverberant rooms under ISO347x series of standards should consider the type of microphones used and corrections.

All the considerations discussed here have related to steady test signal; with impulsive sources it would be necessary to consider the impulse response of the filter network, as this could significantly affect the results. Until more information is available it is best to use a diffuse field microphone until this has been investigated.