# WHITE PAPER

## Challenges in Sound Measurements – Field Testing

**JUNE 2017**

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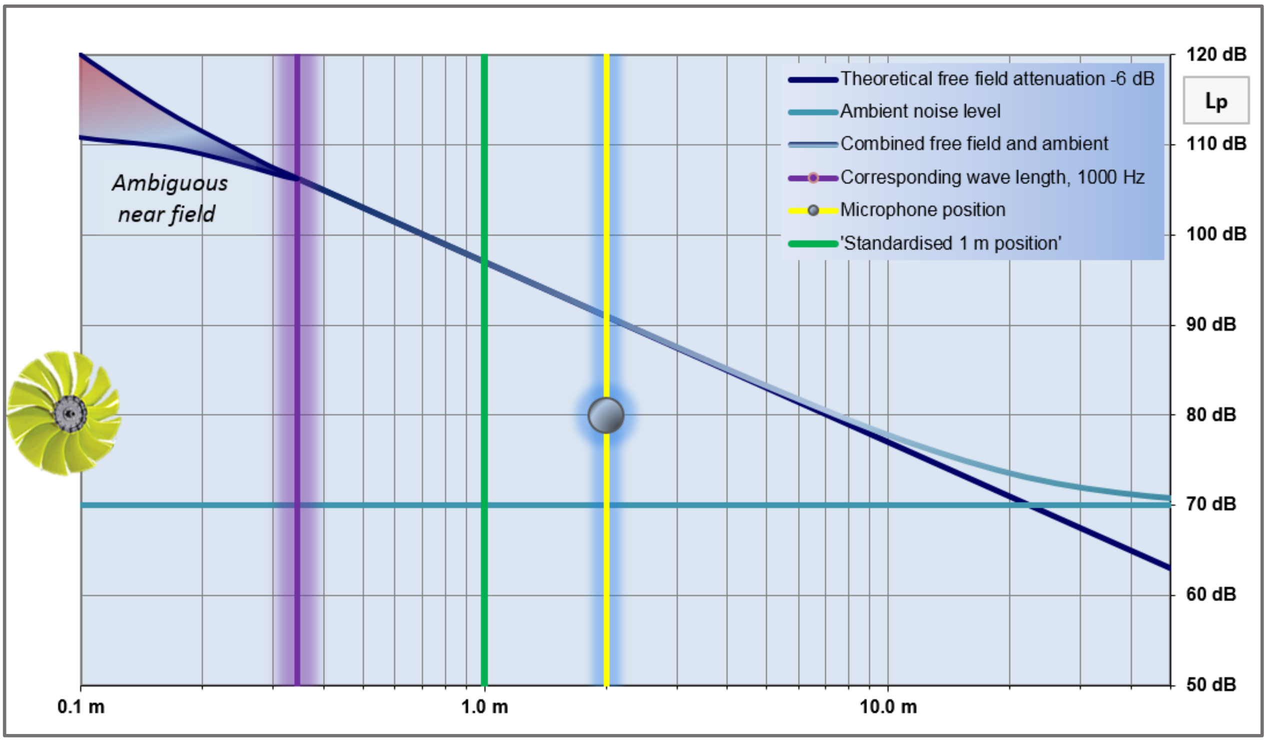
## Introduction

We are often left in a situation where we have to estimate if the conditions for measuring sound power from a noise source in free field test are sufficiently optimal in order to obtain reliable results. The present white paper deals with some of the challenges involved. The paper is backed up by a short video that visualises the often quite complicated conditions. Feel free to watch the video on www.multi-wing.com

## Sound propagation, simplified approach

Assuming that conditions are ideal, one could just make sure that the *free field* conditions were met. A situation like this, using a simplified approach, is shown in the graph below. It assumes that a sound power level, $L_W$, around 105 dB is radiated from a point sound source over a plane, hard surface – in this example an axial fan. This way of presenting is often seen when propagation of sound is illustrated.

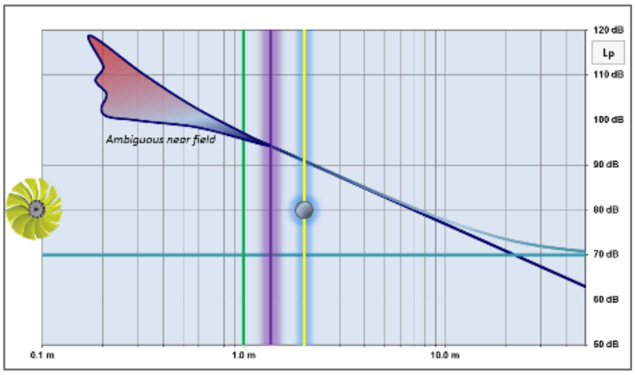
The abscissa shows the logarithmic distance from the source; the ordinate shows the sound pressure level, $L_p$. For a start we assume that the fan only radiates sound at 1 kHz. Hence the nearfield extends to one wavelength, i.e. we get $\lambda_c = a/f$, where a is the speed of sound and f is the frequency. The theoretical limit of the *nearfield* is marked with a purple line at around 0.3 m distance at 20°C.



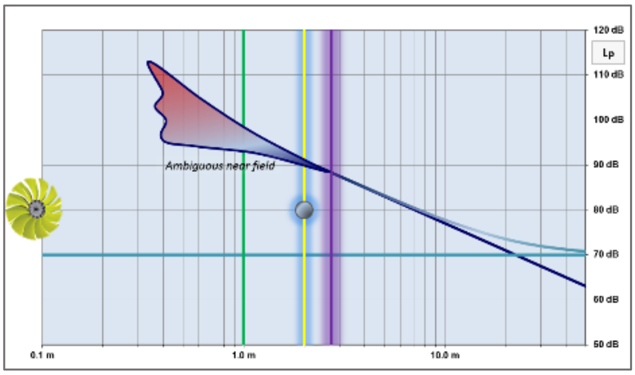

The microphone position that we have chosen in this case is at 2 m distance, indicated by the yellow line. This is well outside the nearfield and the measurement should contain no ambiguous elements. Further we observe a vertical green line. This is a very common value which is referred to in the specifications of many products. We refer to it as a ‘standardised 1 m position’.

The theoretical free field attenuation assumes –6 dB per double distance. This is marked with the dark blue line. In order to account for the background noise, a horizontal light blue line has been added to the plot, assuming a constant 70 dB sound pressure level (SPL) everywhere. As the free field attenuation line starts to approach the background noise, the latter *blends* into the actual SPL, resulting in the curved diverging graph at large distances. This is important to keep in mind: That the background noise is known when the SPL is measured at a large distance.

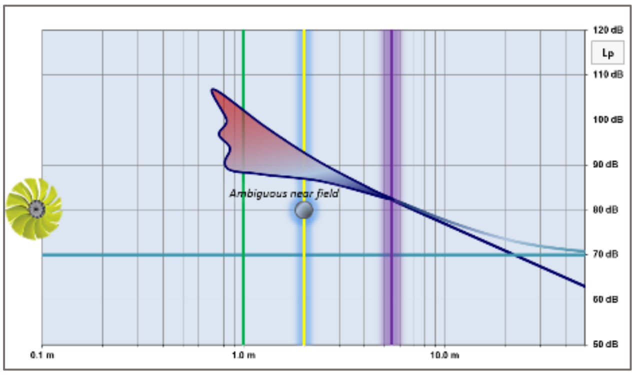
Now let's start lowering the frequency and see what happens. At 250 Hz the nearfield extends to more than the standardised 1 m position. At 125 Hz the microphone is in the nearfield and at 63 Hz the nearfield extends to as much as 5.4 m, with the background noise starting to blend in.



Frequency 250 Hz



Frequency 125 Hz

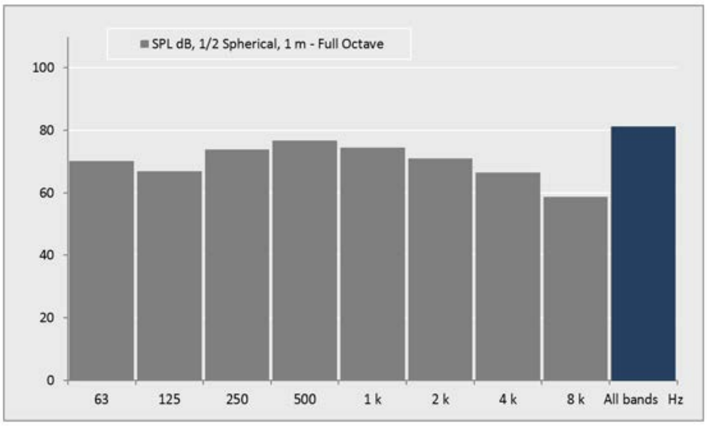


Frequency 63 Hz

One could argue that 63 Hz is a very low frequency that is dampened very strongly when an A-weighting is applied. This is true, but the very long wavelength makes the non-ideal effect very visible as we shall see later. When it comes to fans, also we often find very pronounced contributions from the lower frequencies.

We have chosen to work only with the centre frequencies (63 Hz, 125 Hz, 250 Hz, …), where for example the '63 Hz band' covers frequencies from 44 Hz to 88 Hz.

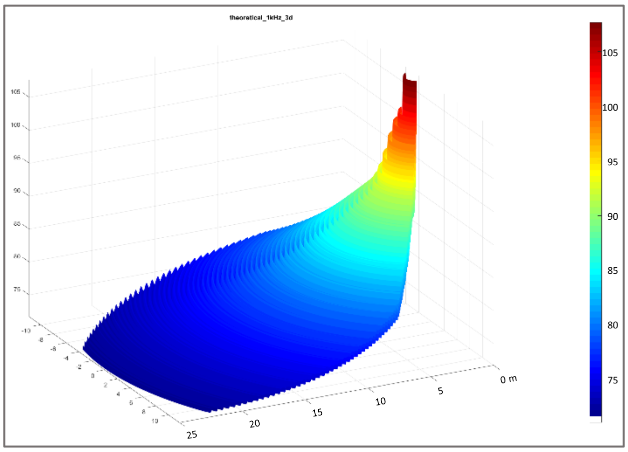
Of course this is a simplified situation but in fact not far from reality since fans mostly produce a high content of tonal noise with a number of overtones, i.e. with contributions in each band. A typical SPL spectrum of a fan is illustrated below, showing all eight octave bands. The term '1/2 Spherical' is referring to propagation over a plane surface (hemi spherical).

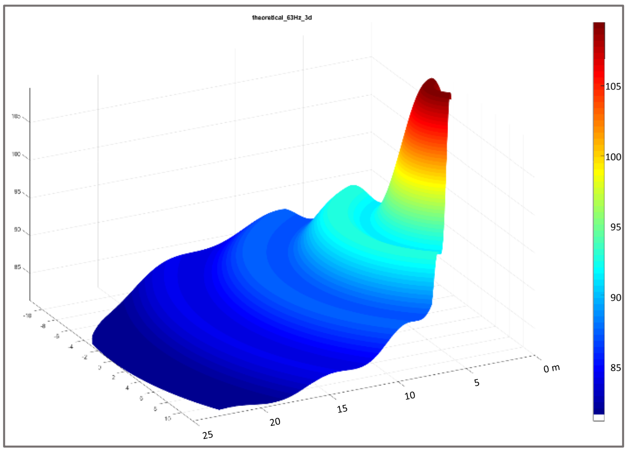



## Sound propagation at ideal conditions

It may look simple: Just make sure that you are one wavelength of the lowest frequency away from the sound source you want to measure. However, the simplified approach, just described, omits a number of important terms in the sound propagation that makes is close to useless.

Without going into too much detail, the sound propagation at ideal conditions, taking into account these effects, is illustrated for a 1 kHz tone in the illustration below on the left-hand side. Calculations were made for a microphone position 1 m above a hard, concrete surface. The decay in SPL at a first glance looks much like the simplified approach – but there is a large difference: There are ripples on the surface, even at distances as far as 25 m away from the source.

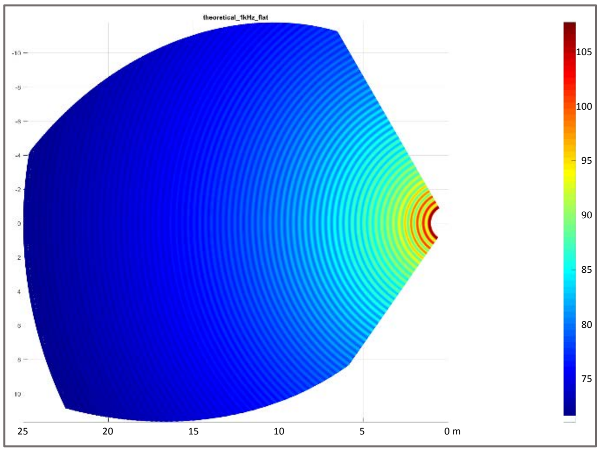


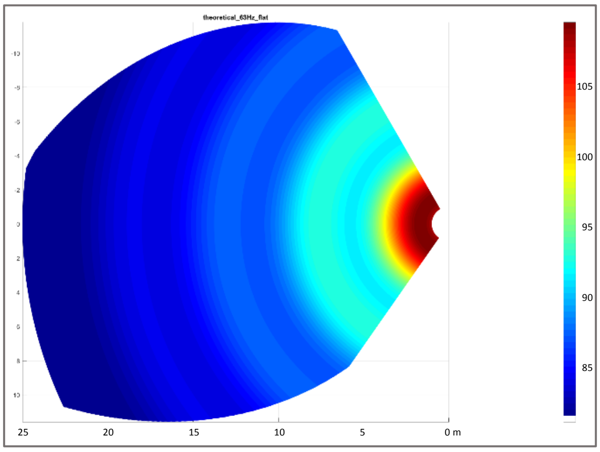




Propagation over a plane hard surface at 1 kHz - and at 63 Hz, topographic view.

As we shall see in the next illustrations (based on the same calculations, but made flat to make them more readable) the fluctuations even at 2.5 m distance are from 90 to 95 dB for the 1 kHz sound source – making it practically impossible to locate a microphone correctly. In essence this means that a simple measurement in front of a fan makes no sense.

For the 63 Hz case, the gradients are not as strong, but there is no simple relationship between the distance and the sound pressure level.




Propagation over a plane hard surface at 1 kHz - and at 63 Hz, flat projection view.

This may seem discouraging. However, using an A-weighted measurement, the allowable deduction is 26.1 dB for the 63 Hz band – which makes these errors less influential. Underneath is shown a table for the A-weighting of a measurement – note that even at 500 Hz a 3.2 dB value can still be deducted from the actual, linear SPL value.

| Band Hz | A-weighting |
|---|---|
| 63 | -26.2 |
| 125 | -16.1 |
| 250 | -8.5 |
| 500 | -3.2 |
| 1 k | 0 |
| 2 k | 1.2 |
| 4 k | 1.0 |
| 8 k | -1.1 |

One thing that, to some extent reduces the problem as the frequency increases, is the fact that the sound source is not a point source. Each part of the fan circumference will produce its contribution to the sound field. These areas will radiate incoherently and from different positions on the circumference. As a result, the large gradients will become more blurred and the error will go down.

The so-called ideal conditions are normally never present. If we refer to the ISO standard 3744, dealing with sound measurements over a flat plane, then the full title reads:

Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – *Engineering methods for an essentially free field over a reflecting plane.*

Paragraph 1.3 defines the ideal case: '*The ideal environment is a completely open space with no bounding or reflecting surfaces other than the reflecting plane(s) (such as that provided by a qualified hemi-anechoic chamber), but procedures are given for applying corrections (within limits that are specified) in the case of environments that are less than ideal.*'

The part of the title written in italics uses the words '*engineering*' and '*essentially*', indicating that some compromises have been made in order to make measurements possible in a real (non-ideal) world.

Now the question is: What is an *essentially* free field? This is something that will be discussed in the next paragraph.

### Sound propagation at real world conditions

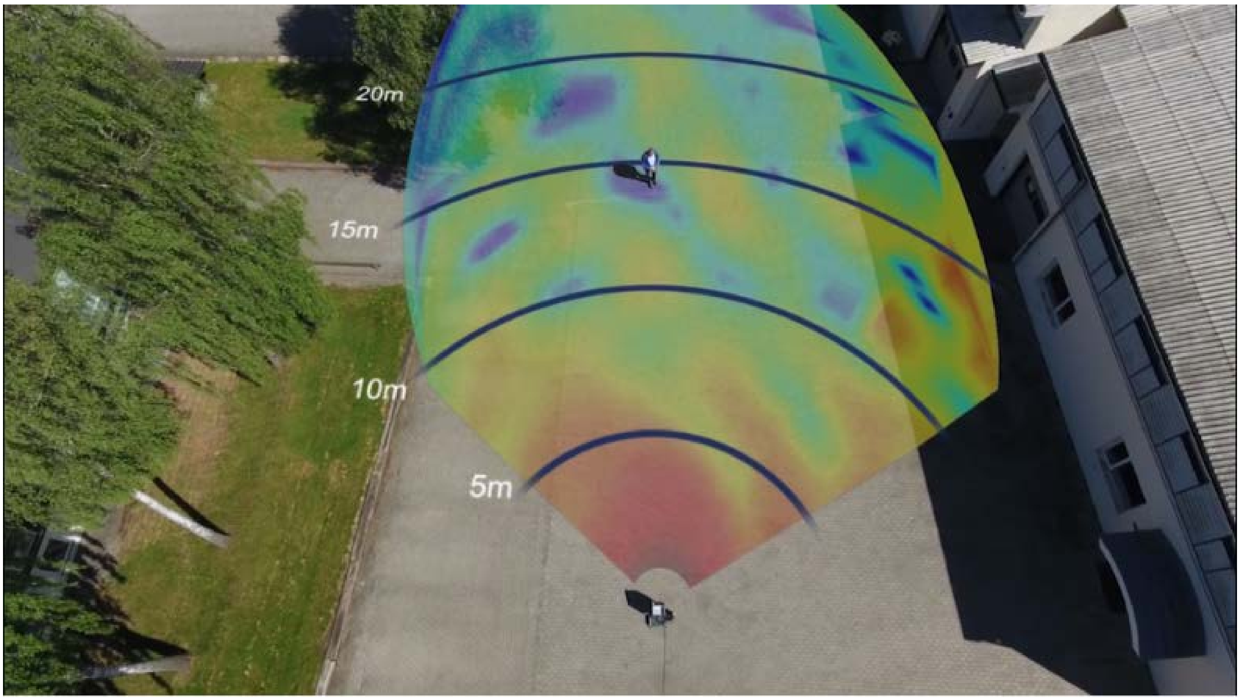
Typical locations in modern world industrial regions offer rather limited space. Areas that would generally be used for free field measurements would be parking areas. The challenge then arises: Is the space an *essentially* free field? There will be buildings, trees, cars and other things that will reflect or absorb the sound. Even the ground could act differently.

ISO 3744 brings this up by suggesting a first qualification test using a reference sound source in paragraph A.1:

'*The first qualification test (absolute comparison test, see A.2) is carried out with a reference sound source (RSS) and can be used outdoors and indoors. This is the preferred procedure for qualifying a test environment, particularly if data in frequency bands are required, and if the noise source under test can be removed from the test site.*'

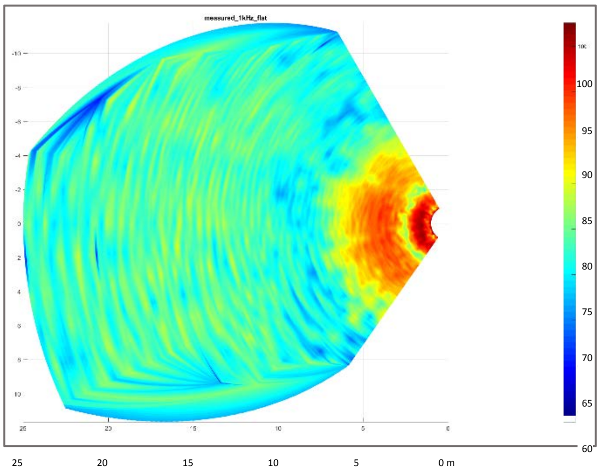
So there is a way to evaluate the performance of a given location. It is not the scope of this white paper to demonstrate the use of ISO 3744 – merely to say that many of the issues associated with sound measurements have been foreseen in this standard.

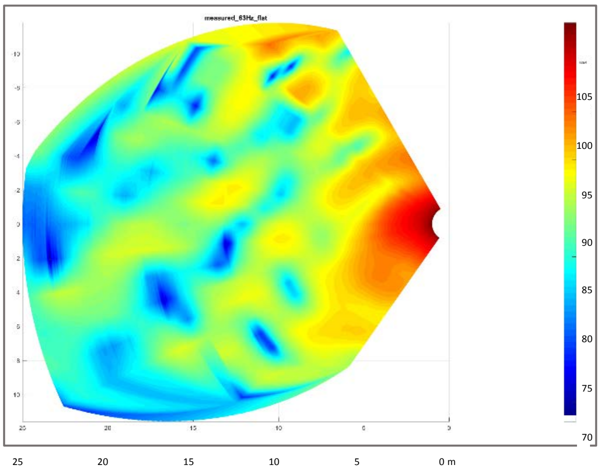
To demonstrate the actual influence of reflecting walls, trees and different absorptions in the test site the examples from the former paragraph were measured in the real world at the Multi-Wing development centre in Denmark. The yard at this location offers some 30 by 30 m of open space.




The illustration shows the parking area between buildings on three sides. Projected onto this are sound measurements made with a microphone connected to a data logger and a position indicator. A loudspeaker is placed in the centre of the radiation pattern and the distances are shown with marked circles.

As with the plots in the former paragraph, the flat projected view data are shown underneath.




Propagation over a plane hard surface at 1 kHz - and at 63 Hz, flat projection view.

The 63 Hz example shows a very complicated sound propagation with a lot of nodes with high as well as low SPL, ranging from some 75 dB to well above 105 dB close to the 1 m circle. Judging from this, the measurement will be close to useless – if it was not for the fact that as much as -26.1 dB reduction is allowed when measuring the lowest band.

The 1 kHz example shows ripples that were identified in the ideal case, but there is a kind of intermediate region (6-8 m), where the level is remarkably lower than the rest of the area, where the alternations in SPL are between 80 dB and close to 90 dB. In fact this would also deem the test field useless for such tests. The situation is remedied to some extend by the effect that was mentioned earlier, namely the incoherent radiation from the blades at different positions on the circumference, blurring the picture. Actually, most of the sound is produced in the clearance between the blade tip and the shroud, creating a large separation between the noise sources. Hence the effect is not as pronounced as the 1 kHz example shows.

At higher frequencies the aerodynamic noise generally contributes more to the sound spectrum than the tonal noise and the associated harmonics. This type of noise is far more evenly distributed in the spectrum and consequently the large variations in SPL in this region tend to vanish.

## Other effects and literature

The discussion, so far, has mainly been focussing on the test field. There are, however, also other effects that influence the sound propagation. Amongst these, the influences of wind shear and turbulence, temperature gradients and absorption from the ground are important.

There are several advanced articles on the subject of sound propagation. Some are listed here:

Noise Control, Outdoor Sound Propagation, J. S. Lamancusa, Penn State, http://www.mne.psu.edu/lamancusa/me458/10_osp.pdf

Sound wave propagation from a point source over a homogeneous surface and over a surface with an impedance discontinuity, http://asa.scitation.org/doi/pdf/10.1121/1.395657

Sound propagation over a surface with varying impedance: A parabolic equation approach, http://asa.scitation.org/doi/10.1121/1.403758

Further pressure and air temperature have some influence, however small. These are well described in the ISO 3744 standard, section G.