

# Unattended noise monitoring: how to fulfill IEC 61672 sound level meter standard for 0 degree and 90 degree reference directions with the same device

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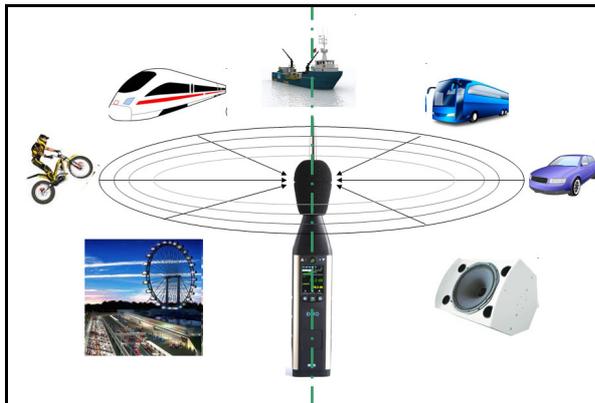
## ABSTRACT

Unattended noise measurements are more and more common for noise assessment in the environment. Multiple sources are usually measured with a random position with respect to the measurement point. Noise generated by ground transportation, leisure activities, construction sites is coming from all directions, although mainly the horizontal direction. Placed vertically and configured for a reference direction of 90° from its axis, the goal is to meet the requirements of the IEC 61672 standard on sound level meters taking into account noise incidence from the horizontal direction. The main technical difficulty is the criterion for the maximum level difference allowed between two random incidence angles (directivity). The objective can be fulfilled using a cone-shaped device on top of the microphone. When measuring attended noise with the instrument in hand, the sound level meter must be pointed at the source according to standard IEC 60651. The purpose of the paper is to describe the different research & development phases to fulfill IEC 61672 sound level meter standard for 0° and 90° reference directions with the same device.

## INTRODUCTION

For sound level measurements performed in accordance with IEC 61672 [1], the sound level meter is supposed to be pointed towards the source (0° incidence).

For unattended measurements, the direction from the source is generally unknown. Except for aircraft noise measurements, the sources are located on the ground, see Figure 1; therefore the optimal position for unattended noise measurements is to setup the measurement device vertically and to design it in such a way that it fulfills the IEC 61672-1 standard for ground sources (90° incidence):



**Figure 1.** Ground sources and sound level meter orientation for 90° incidence.

Our goal was to achieve a sound level meter design able to fulfill both 0° (for aircraft noise [2] and measurement pointing at the source) and 90° reference directions (for unattended measurements on ground sources).

## DESIGN CONSTRAINTS

### IEC 61672-1: directional response limits

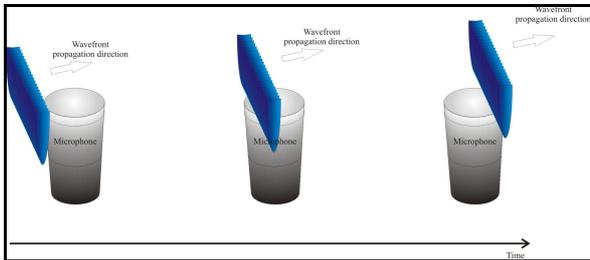
Table 1 gives directional response requirements for the configuration of a sound level meter as stated in the instruction manual for the normal mode of operation. The specifications in Table 1 apply for plane progressive sound waves at any sound-incidence angle within the indicated ranges, including the reference direction. At any frequency, the design goal is equal response to sounds from all directions of sound incidence (§ 5.3 of IEC 61672-1 standard).

**Table 1.** Maximum absolute difference in displayed sound levels for class 1 at any two sound-incidence angles within ±θ degrees from the reference direction (extended by the expanded uncertainty of measurement for demonstration of compliance to the limits given below).

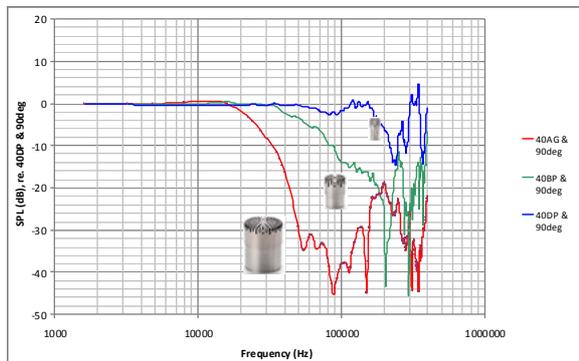
Frequency [kHz]	Expanded uncertainty [dB]	θ = 30°	θ = 90°	θ = 150°
0.25 to 1	0.3	1.3 dB	1.8 dB	2.3 dB
> 1 to 2	0.5	1.5 dB	2.5 dB	4.5 dB
>2 to 4	0.5	2.0 dB	4.5 dB	6.5 dB
>4 to 8	1.0	3.5 dB	8.0 dB	11.0 dB
>8 to 12.5	1.5	5.5 dB	11.5 dB	15.5 dB

**Condenser microphones behavior at high frequencies; Limitations due to diameter**

High frequency response depends on the diameter of the diaphragm, see Figure 2 and Figure 3:



**Figure 2.** Influence of propagation on a microphone for a 90° incident wave.



**Figure 3.** Influence of the microphone diameter on the frequency response (90° incidence) for 1/2" (red), 1/4" (green) and 1/8" (blue) microphones.

The frequency response is improved when the diameter of the diaphragm decreases.

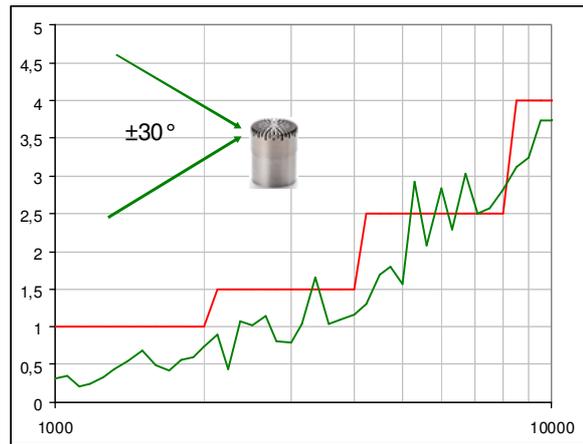
Nevertheless the positive effect is altered by a higher background noise (thermal noise), see Table 2:

**Table 2.** Typical characteristics for different microphone diaphragm diameters

Microphone diaphragm diameter	1/2"	1/4"	1/8"
Sensitivity (typical)	50 mV/Pa	4 mV/Pa	1 mV/Pa
Thermal noise (typical)	15 dBA	30 dBA	40 dBA

1/2" microphones are usually selected, as being the best compromise between costs, frequency response and background noise for general environmental noise assessment.

**Focus on 1/2" microphones**



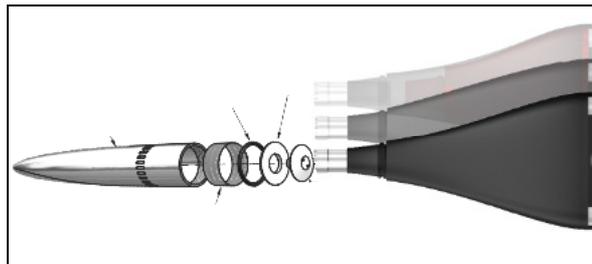
**Figure 4.** Directional response (green) of a 1/2" microphone for  $\theta = 30^\circ$  (reference direction 90°). Tolerance values of IEC 61672-1 (red) without expanded uncertainty.

Standards 1/2" microphones do not fulfil IEC standard (directional response) for the reference direction 90° configuration. The directional response (maximum absolute difference in displayed sound levels for class 1 at any two sound-incidence angles within  $\pm 30^\circ$ , 90° and 150°) is out of tolerance.

**SOLUTION: ACOUSTIC CONE**

**Shape of DUO sound level meter body and distance of the microphone to the body**

Various shapes of the mechanical design of DUO [3] at the early stage, as well as several distances between the microphone and the body were made and tested using 3D prints; see Figure 5 and Figure 6:



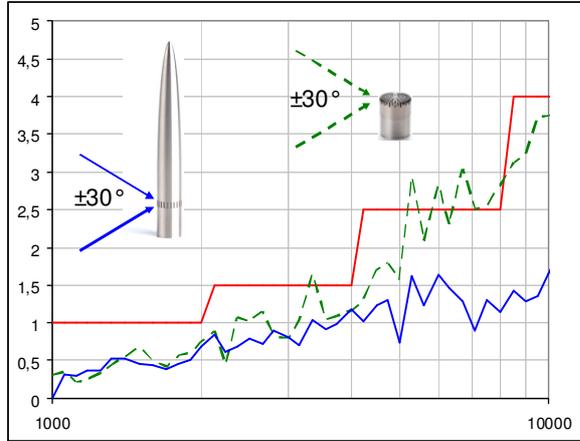
**Figure 5.** Different shapes for the upper part of the DUO sound level meter body tested for optimum frequency response and directional response.



**Figure 6.** Electro acoustic tests performed on 3D prints to validate the mechanical design of the body.

**Directional response results**

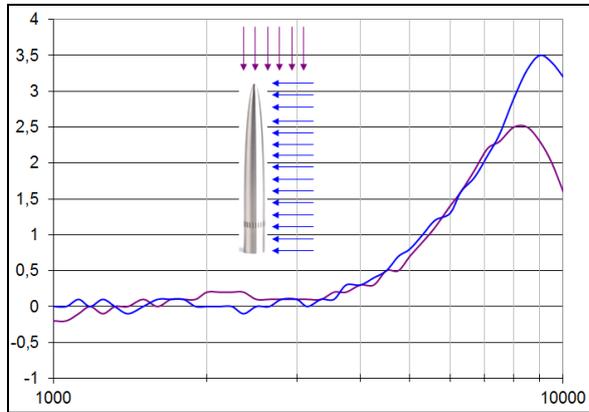
$\theta = 30^\circ$  directional response is displayed in Figure 7, as an example of requirement to achieve. The benefit of the cone corresponds to the difference between the green dot curve and the blue curve.



**Figure 7.** Directional response of DUO with acoustic cone (blue) for  $\theta = 30^\circ$  (reference direction  $90^\circ$ ); Tolerance values of IEC 61672-1 (red) without expanded uncertainty.

**INFLUENCE OF THE CONE ON THE FREQUENCY RESPONSE**

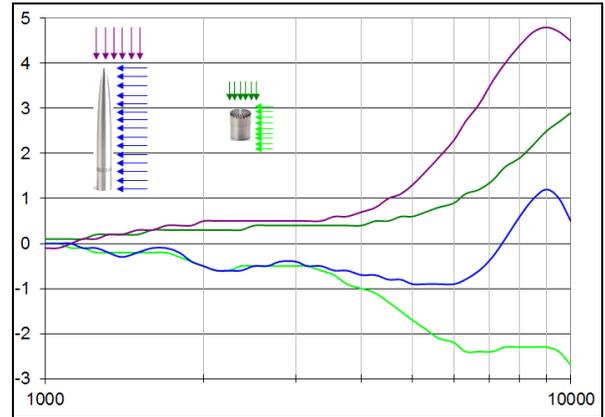
When the cone is mounted on top of the microphone, its influence depends on the incident wave. Figure 8 has been obtained by subtracting the frequency response of the microphone *with* cone and the frequency response of the microphone *without* cone:



**Figure 8.** Influence of the cone for  $90^\circ$  incidence (blue). Influence of the cone for  $0^\circ$  incidence (violet).

**OVERALL INFLUENCE**

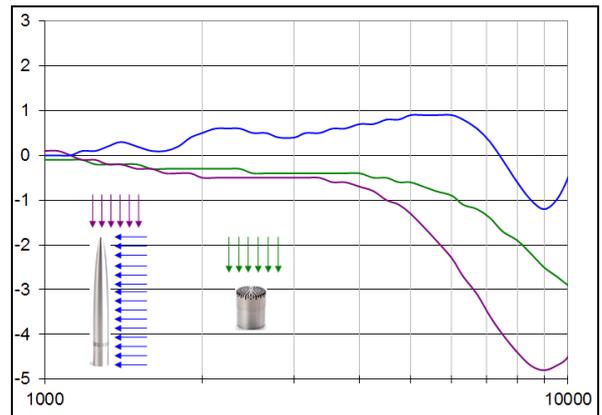
Figure 9 shows the overall frequency response of the microphone + cone assembly for different configurations. The green curve corresponds to the frequency response of the microphone at  $0^\circ$ . It is not a free field microphone; its specific characteristics were designed to minimize the electronic corrections to be applied for the different configurations.



**Figure 9.** Overall frequency response results for 4 different configurations: without noise cone at  $0^\circ$  (green) and  $90^\circ$  (light green), and with noise cone at  $0^\circ$  (violet) and  $90^\circ$  (blue)

**ELECTRONIC CORRECTIONS**

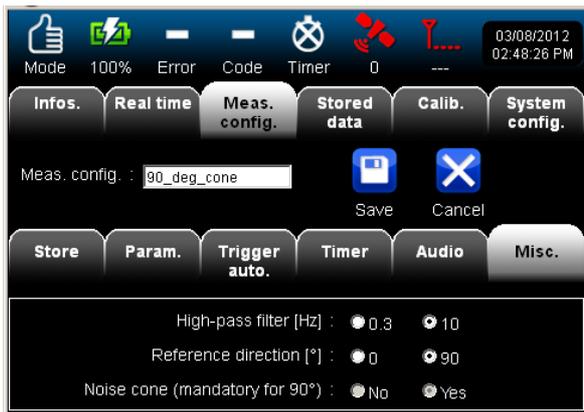
The electronic corrections shown in Figure 10 are implemented in DUO. Please note the absence of correction for  $90^\circ$  incidence without cone as this configuration does not meet the standard:



**Figure 10.** Electronic corrections implemented in DUO.

**SETUP IN DUO**

The configuration used for the measurement is part of the measurement setup. Therefore the user can store different measurement configurations according to the type of measurement that will be performed. See Figure 11 as an example of measurement configuration setup of DUO (configuration  $90^\circ$  with cone, corresponding to unattended ground noise measurements with the instrument mounted vertically):



**Figure 11.** DUO measurement configuration setup page for reference direction configuration. As 90° is selected, the user cannot select “No” for noise cone (radio button forced to “Yes”).

**OTHER FACTORS**

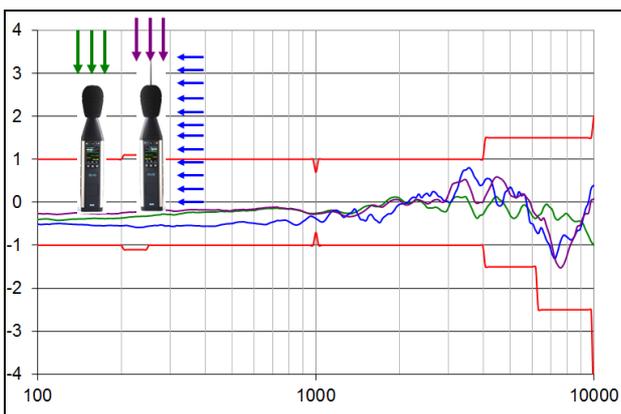
During the design phase, several additional factors had to be taken into account:

- Influence of the shape of the body
- Influence of the two different wind screens (classical and integral)

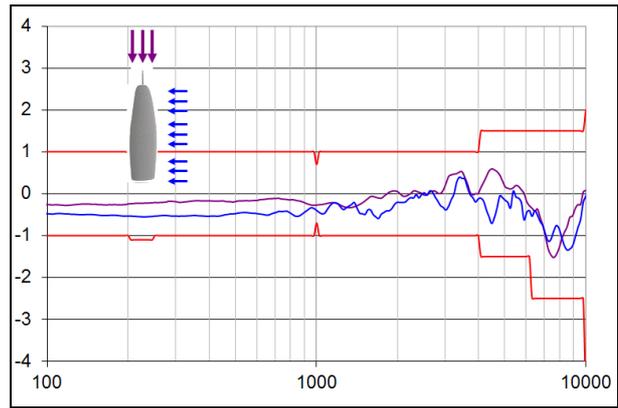
The following section illustrates the final frequency responses taking into account the influence of these factors.

**RESULTS**

Figure 12 and Figure 13 show results on DUO serial number 10174; measurements performed at LNE (Laboratoire National d’Essais) taking into account the free field correction factor:



**Figure 12.** Frequency response for classical wind screen, without noise cone for 0° (red) reference direction, with noise cone for 0° (violet) and 90° reference direction (blue).



**Figure 13.** Frequency response for integral protection foam, 0° (violet) and 90° (blue) reference directions.

**CONCLUSION**

The requirement for DUO as a sound level meter used for unattended measurements made mandatory the possibility to setup both configurations: 0° and 90° reference directions. A key to success has been the close cooperation between the two companies ACOEM/01dB and G.R.A.S. development teams. The fact that we took into account the acoustic front end design at the early stage of the development allowed determining and optimizing the constraints: position of the microphone, shape of the body of the sound level meter, cone and wind screens characteristics. DUO is the first and unique (March 2012) sound level meter approved in France [4], in Germany [5] and in Switzerland [6] with both reference directions 0° and 90°.

**ACKNOWLEDGMENTS**

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**REFERENCES**

- [1] IEC 61672-1 2002-05 Electroacoustics-sound level meters – part 1: Specifications
- [2] ISO 20906:2009 Acoustics - Unattended monitoring of aircraft sound in the vicinity of airports
- [3] 01dB, a brand of ACOEM: DUO Product data sheet: NOT 1507 – December 2011
- [4] CERTIFICAT D’EXAMEN DE TYPE No LNE-21674 rev 0 du 21 juillet 2011 delivered by LNE (Laboratoire National d’Essais), France
- [5] PTB-1.63-4052726 delivered on the 6th February 2012 by PTB (Physikalisch-Technische Bundesanstalt), Germany
- [6] Zulassungszertifikat CH-A3-12096-00 delivered on the 20<sup>th</sup> February 2012 by Bundesamt für Metrologie METAS, Switzerland.