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A unique noise monitoring terminal optimised for either community or airport noise

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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. The purpose of the paper is to describe the research &development phases to fulfil IEC 61672 sound level meter standard for 0° and 90° reference directions with the same device. Some operating examples will be presented that emphasise the major interest of this unique noise monitoring terminal optimised for either community or airport noise incidences.

1 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 fig. 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):

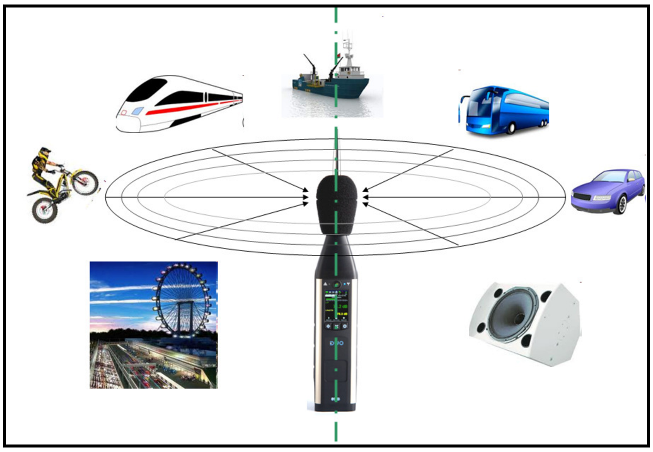

Figure 1: Sound reduction index as a function of angle of incidence

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).

2 Design constraints

2.1 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 above)

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

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

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

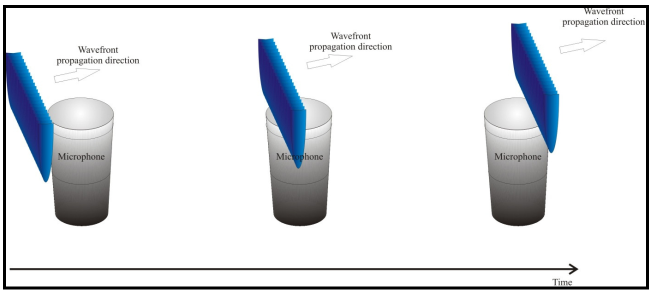

Fig. 2: Influence of propagation on a microphone for a 90° incident wave

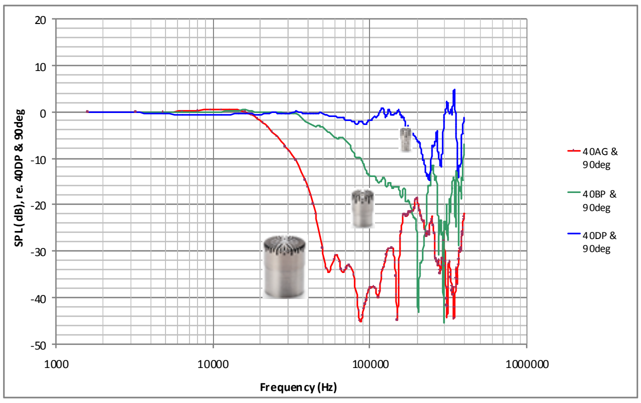

Fig. 3: Influence of the microphone diameter on the frequency response (90° incidence) for 1/2’ (red),1/4’ (green) and 1/8’ (blue) microphones.

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.

2.3 Focus on 1/2’ microphones

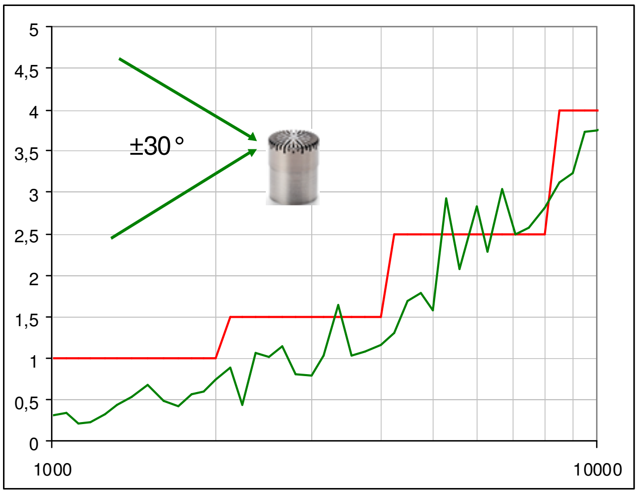

Fig. 4: In green directional response of a 1/2’ microphone for θ = 30° (reference direction 90°); in red, tolerance values of IEC 61672-1 without expanded uncertainty

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 ±30°, 90° and 150°) is out of tolerance.

3 Solution: acoustic cone

3.1 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 fig. 5 and fig. 6:

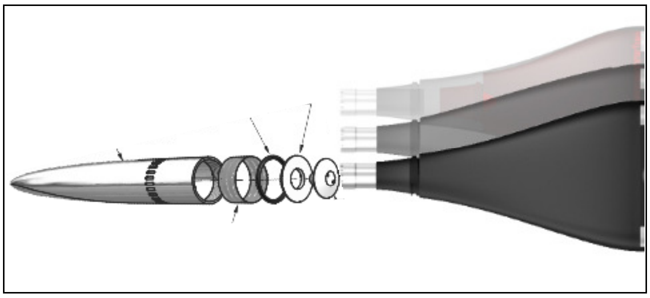

Fig.5: Different shapes for the upper part of the DUO sound level meter body tested for optimum frequency response and directional response

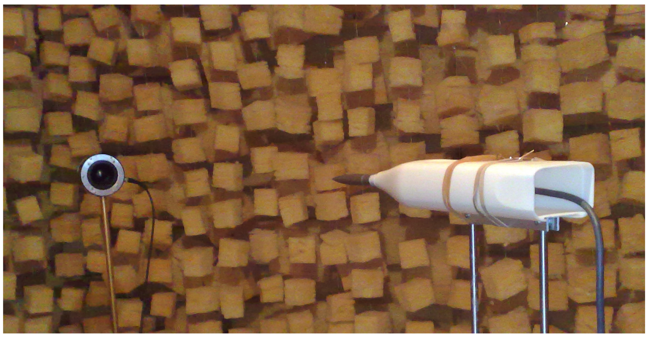

Fig. 6: Electro acoustic tests performed on 3D prints to validate the mechanical design of the body

3.2 Directional response results

θ = 30° directional response is displayed in fig. 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.

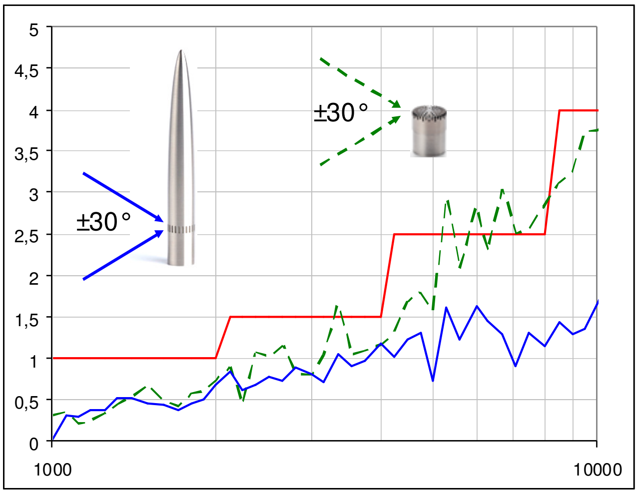

Fig. 7: In blue, directional response of DUO with acoustic cone for θ = 30° (reference direction 90°); in red, tolerance values of IEC 61672-1 without expanded uncertainty

4 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. Fig. 8 has been obtained by subtracting the frequency response of the microphone *with* cone and the frequency response of the microphone *without* cone:

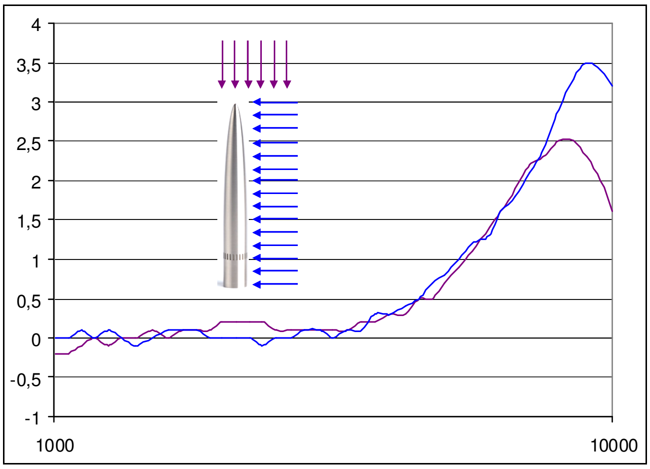

Fig. 8: In blue influence of the cone for 90° incidence; in violet influence of the cone for 0° incidence

5 Overall influence

Fig. 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°. It is not a free field microphone; its specific characteristics were designed to minimize the electronic corrections to be applied for the different configurations.

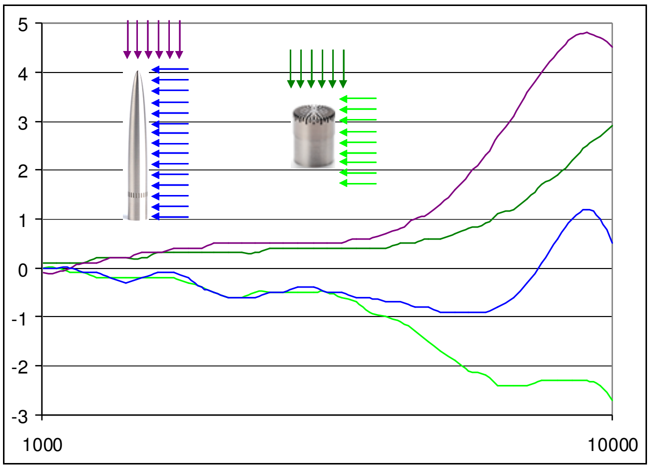

Fig. 9: Overall frequency response results for 4 different configurations: without noise cone at 0° (green) and 90° (light green), and with noise cone at 0° (violet) and 90° (blue)

6 Electronic corrections

The electronic corrections shown in fig. 9 are implemented in DUO. Please note the absence of correction for 90° incidence without cone as this configuration does not meet the standard:

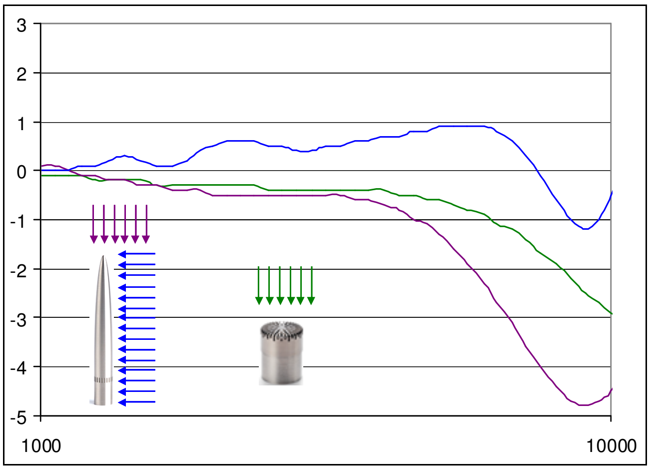

Fig. 10: Electronic corrections implemented in DUO

7 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 fig. 10 as an example of measurement configuration setup of DUO (configuration 90° with cone, corresponding to unattended ground noise measurements with the instrument mounted vertically):

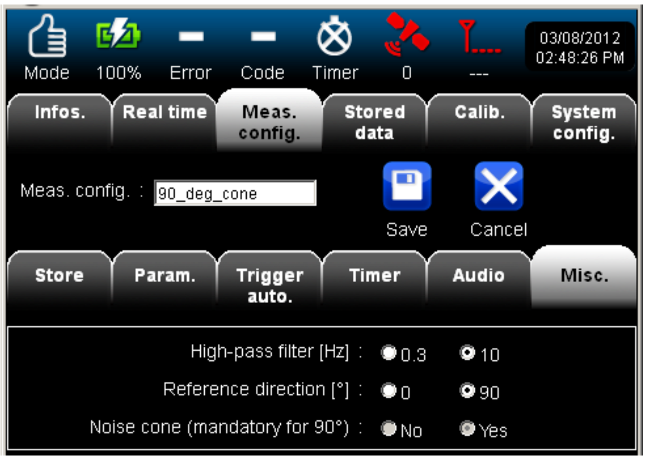

Fig. 11: DUO measurement configuration setup page for reference direction configuration. As 90° is selected, the user cannot select "No" for noise cone (radio button forced to "Yes")

8 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.

9 Results

Fig. 11 and Fig. 12 show results on DUO serial number 10174; measurements performed at LNE (Laboratoire National d'Essais) taking into account the free field correction factor:

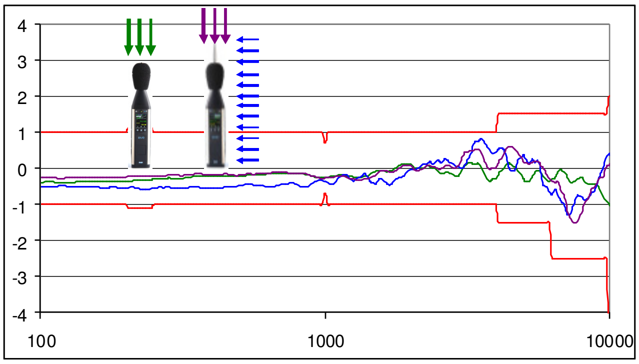

Fig. 12: Frequency response for classical wind screen, without noise cone for 0° (red) reference direction, with noise cone for 0° (violet) and 90° reference direction (blue)

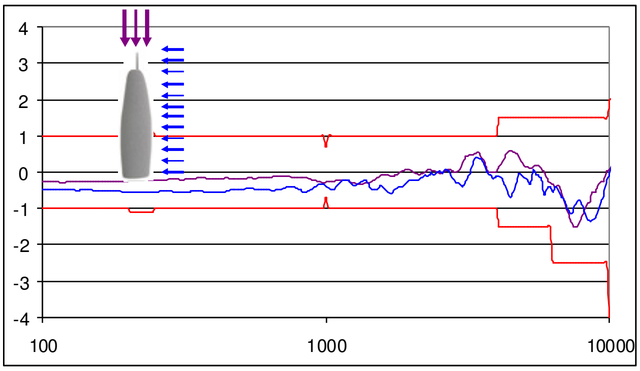

Fig. 13: Frequency response for integral protection foam, 0° (violet) and 90° (blue) reference directions

10 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 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

Grateful acknowledgments to Per Rasmussen and Jørgen Bække from G.R.A.S. for their active participation on the different stages of the development of DUO sound level meter [3].

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 20th February 2012 by Bundesamt für Metrologie METAS, Switzerland.