NOSE CONE DEVICE AND BUILT-IN CALIBRATION CHECK AS ESSENTIAL FEATURES OF A STAND-ALONE INSTRUMENT FOR UNATTENDED MID- AND LONG-TERM NOISE MEASUREMENTS

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1. INTRODUCTION

Environmental noise generated by ground transportation, construction sites or recreational activities, is coming from all directions, and such multiple sources are usually located at random positions with respect to the measurement point. With the instrument placed vertically (while sources mainly coming from a reference direction of 90° from its axis), the goal is to meet the requirements of the IEC 61672-1 standard [1] on sound level meters taking into account noise incidence from the horizontal direction. Emphasis will be given on the main technical difficulty and the adequate solution meeting the standard requirement.

In addition, mid- to long-term remote operation of the device imposes a constant control of the measurement quality. At first an acoustic calibration of the instrument is made during installation on site. Then during unattended operation of the instrument, the integrity of the complete measurement chain (including the microphone) is automatically tested, relying on a built-in electrical check. The test consists in injecting a sinusoidal charge into the microphone membrane, at selected frequencies. The (partly user-defined) multiple-frequency check allows assessing of a possible degradation of the microphone as well as the electronic components.

2. 0° and 90° incidence directions

In unattended noise measurement situations, the direction from the source is generally unknown. Apart from aircraft noise, the sources are located on the ground. The optimal position of the sound level meter for unattended noise measurements is thus vertical, with an instrument design so as to fulfill the IEC 61672-1 standard for ground sources (90° incidence). Our goal was to achieve a sound level meter design able to fulfill both 0° (aircraft noise [2] and measurement pointing at the source) and 90° reference directions (ground source noise measurements).

Additionally the risk of wrong measurements in environmental noise assessment must be reduced as low as possible. A built-in electrical check (multi-frequencies charge injection) allows for testing the whole measurement chain, including the microphone and offers the advantage of a better assessment of a possible degradation of the microphone membrane or of the electronic components. This will be discussed on the second part of this paper.

2.1 Design constraints

IEC 61672-1 gives directional response requirements for the configuration of a sound level meter as stated in the instruction manual for the normal mode of operation or for those components of a sound level meter that are intended to be located in a sound field. The specifications apply for plane progressive sound waves at any sound-incidence angle within the indicated range (focus on +/- 30°), including the reference direction. At any frequency, the design goal is to get equal response to sounds from all directions of sound incidence (§ 5.3 of [1]).

High frequency response depends on the diameter of the diaphragm: they are improved when the diameter of the diaphragm decreases. Nevertheless the positive effect is altered by a higher background noise. As a consequence 1/2' microphones are usually selected, as being the best compromise between costs, frequency response and background noise for environmental noise assessment.

2.2 Solution: Acoustic Cone

Various shapes of the mechanical design of DUO at the early stage, and several distances between the microphone and the body were made and tested using 3D prints:

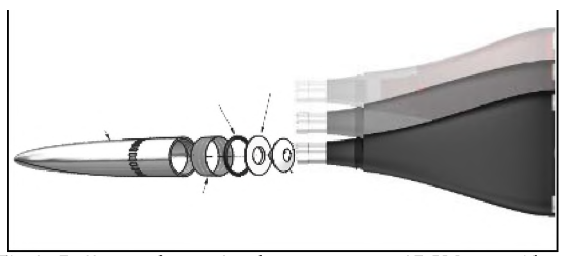

Fig.1: Different shapes for the upper part of DUO sound level meter body tested for optimum frequency/directional response

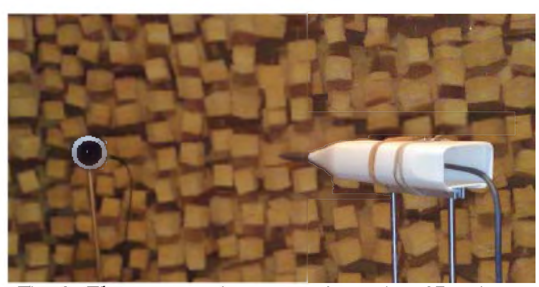

Fig. 2: Electro acoustic tests performed on 3D prints to validate the mechanical design of the body

2.3 Directional response results

θ = 30° directional response is displayed below, as an example of requirement to achieve. The benefit of the cone corresponds to the difference between the green and the blue curves.

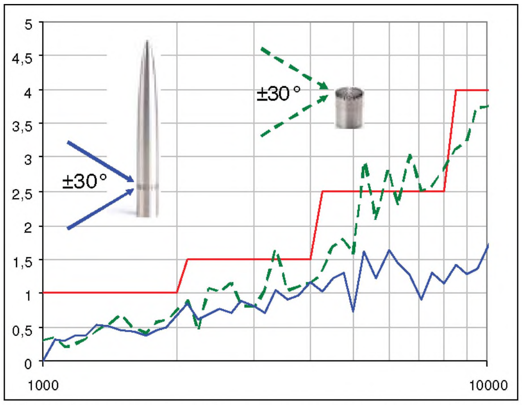

Fig. 3: In blue, directional response of DUO [3] with acoustic cone for θ = 30° (reference direction 90°); in red, tolerance values of IEC 61672-1 without expanded uncertainty

3. BUILT-IN ELECTRICAL TESTS

3.1 Multi-frequencies charge injection principle

The test consists in injecting a stable reference signal though a reference capacitor that "simulates" an acoustic signal at the microphone output (see the dash lines in Fig. 4 below):

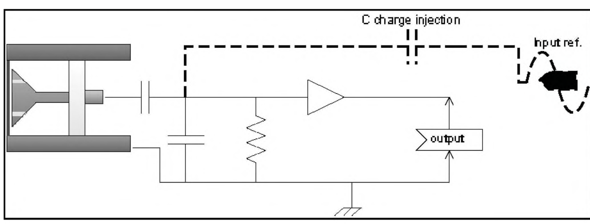

Fig 4: charge injection principle

The reference signal is a frequency user defined sine at a selectable level between 0 and 5 V peak. The capacity for the reference C charge injection is typically around 0.2 pF.

The test consists in creating reference values on a valid system and measure through the sound level meter measurement chain itself the difference in dB with the current situation. The value of the deviation will be representative of a variation of the system.

Charge injection will behave as an impedance comparison between the condenser microphone and the charge injection reference capacitor. If the impedance of the microphone is changed (typically a mechanical damage of the active part of the membrane that will change its capacity) the charge injection method will detect it.

3.2 Test conditions

This test consists in injecting a stable reference Tests were performed in an anechoic room at LNE (French Laboratoire National d'Essais), with DUO used in vertical position.

3.3 Checking description

For each test, a microphone is damaged on purpose and the following measurements are performed before/after damage:

- A-weighted background noise level
- Sensitivity @ 1 kHz
- Multi-frequencies charge injection response at 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz

Relying on this procedure we could successfully detect the following list of defaults:

- Punching of the microphone membrane
- Water drop on the microphone membrane
- Light & heavy dust on the microphone membrane
- Shock on the edge of the microphone
- Small & large cuts on the edge of the microphone
- Bad contact at the inner pin of the microphone

4. DISCUSSION AND CONCLUSIONS

The requirement for DUO [3] as a sound level meter used for unattended measurements made mandatory the possibility to setup 0° and 90° reference directions for capturing all types of sources. A key to success has been the close cooperation between the 01dB and G.R.A.S. R&D teams. Taking 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.

In addition, multi-frequencies CIC is identified as a very useful tool for ensuring reliable measurements between two calibrations on unattended measurement systems. When performed periodically automatically and remotely (one to four times a day) this test will allow controlling the stability of the noise measurement equipment and securing the validity of the measurement between two checks.

DUO [3] is the first and single sound level meter approved in France [4], in Germany [5] and in Switzerland [6] with both reference directions 0° and 90°.

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" – December 2011

[4] Certificat d'examen de type LNE-21674 (21 juillet 2011) delivered by LNE (Laboratoire National d'Essais), France

[5] PTB-1.63-4052726 delivered the 6th February 2012 by PTB (Physikalisch-Technische Bundesanstalt), Germany

[6] Zulassungszertifikat CH-A3-12096-00 (20th February 2012) by Bundesamt für Metrologie METAS, Switzerland.

[7] NF S31-010 December. 1996 « Acoustique -- Caractérisation et mesurage des bruits de l'environnement - Méthodes particulières de mesurage »

[8] IEC 61672-3 2006-10 "Electroacoustics-sound level meters – part 3: Periodic Tests"