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An automatic method to detect defaults in the measurement chain of a sound level meter, used for unattended noise measurements

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The built-in electrical check (multi-frequencies charge injection) allows for testing the whole measurement chain, including the microphone. It consists in injecting a sinusoidal charge (1 or 2 levels) into the microphone membrane, at selected frequencies. The principle is to collect reference values (initialization stage) and to check over time if the deviation between reference values and measured values exceeds a maximum predefined deviation value. A multiple-frequency check offers the advantage of a better assessment of a possible degradation of the microphone membrane or of the electronic components. The checking procedure lasts from 10 to 30 seconds and automatically occurs during the measurement, logged values before and after the checking clearly separated, so to make their validation easier. The purpose of the paper is to describe the results obtained for different types of defaults in the measurement chain.

1 Introduction

The risk of wrong measurements in environmental noise assessment must be reduced as low as possible. The sound level meters or the equivalent measurement chains, including the associated sound calibrator, have to be periodically calibrated by the manufacturer or in a metrology laboratory. These calibrations ensure the traceability to International System of Units but should be carried out at least every second year. The IEC 61672-3 standard [1] describes such a periodic tests of sound level meters.

The main way to reduce the risk of biased measurements is to calibrate the measuring device before each measurement; it is typically a daily control. The calibration is followed, if necessary, by an adjustment, i.e. a calibration factor correction. Often the test codes require checking also the calibration at the end of the measurement, to verify the absence of failure during the measurement.

This is a common and simple method to check if the measurement chain remains stable over time. The sound calibrator allows detecting a change in the sensitivity of the microphone. A sudden change in the microphone sensitivity leads us to think that a fault has appeared since the last calibration. A slow evolution of the calibration factor can also be a warning of a microphone aging.

This practice is not found to be sufficient because the sound calibrators used are mainly single frequency (usually 94dB @ 1000 Hz) and therefore cannot detect defaults at other frequencies.

Fig. 1 shows a picture of a damaged microphone and Fig.2 shows the corresponding frequency response. In this particular example, the frequency response proves that the microphone is fully unusable even though its sensitivity at 1000 Hz is not affected. A single calibration at 1000 Hz would therefore not detect the microphone degradation.

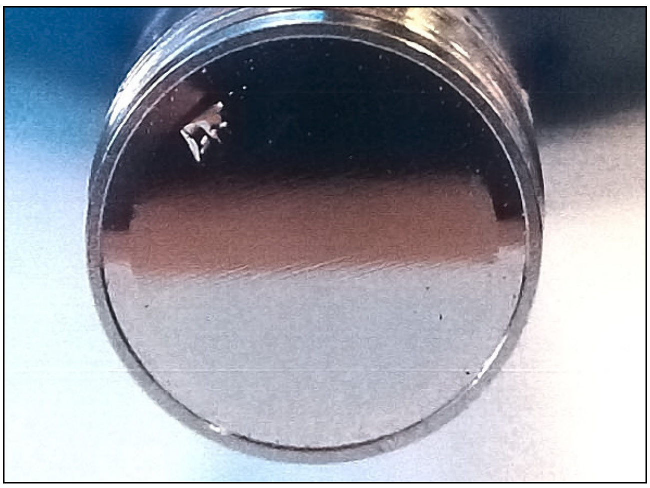

Fig.. 1: microphone with damaged membrane

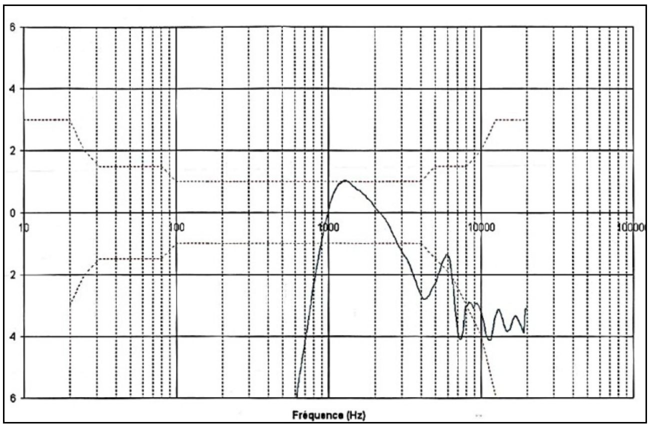

Fig. 2: corresponding frequency response

As a result, it is always recommended to make more extensive checks from time to time, more frequently than the periodic tests carried out by the manufacturer or by a metrology laboratory. Such checks are required in some standards, becoming mandatory: see § 4.84.automatic check in the ISO 20906 standard [2] and see annex A in NFS 31-010 standard [3] with a six-month periodicity.

This paper can also be of interest by showing the link between some physical damages in the microphone, visible or not (bad contact) and its frequency response or its background noise level.

2 Multi-frequencies charge injection principle

This 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. 3:

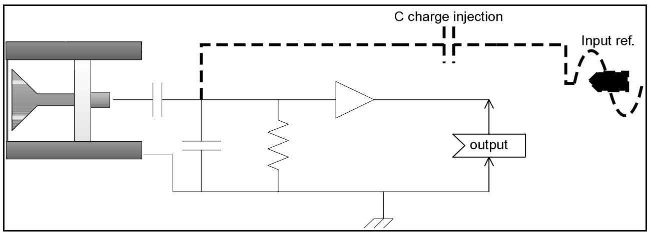

Fig 3: charge injection principle

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 C 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 Test conditions

Tests are performed in one of the anechoic rooms at LNE (Laboratoire National d'Essais), the selected instrument, DUO [4], is used in vertical position:

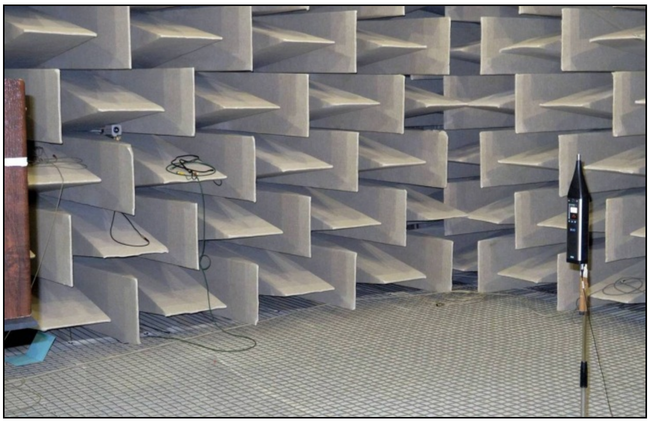

Fig. 4: Test set-up with DUO in vertical position

4 Checking description:

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

- A-weighted background noise level (measured around 18 dBA when no default)
- Sensitivity @ 1 kHz
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz

The frequency response is also measured and is used as the reference: if the frequency response shows a default (red curves in the following figures), will the checking procedure detect it?

5 Defaults made on microphones

The following defaults have been created on different microphones:

- Punching of the membrane
- Water drop on the membrane
- Light dust on the membrane
- Heavy dust on the membrane
- Shock on the edge of the microphone
- Small cut on the edge of the microphone
- Large cut on the edge of the microphone
- Bad contact at the inner pin of the microphone

6 Tests results and analysis

6.1 Punching of the membrane

Fig. 5: membrane punched

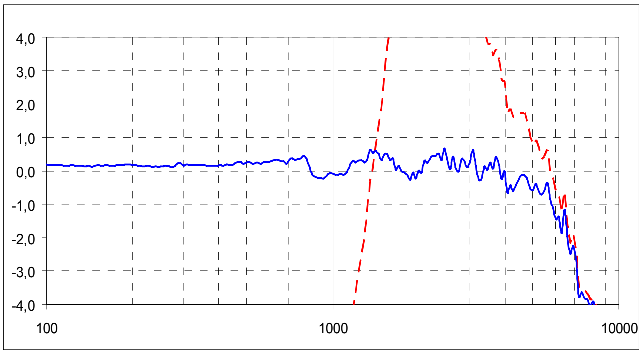

Fig. 6: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: -7 dB
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: From -0.36 dB to -0.93 dB

This case is very similar to the example given in the introduction but with a shifted frequency response. Hopefully in that case the calibration procedure will detect the default.

Multi-frequencies charge injection response is sensitive to this default; the mechanical damage has changed the capacity of the microphone.

6.2 Water drop on the membrane

Fig. 7: water drop on the membrane

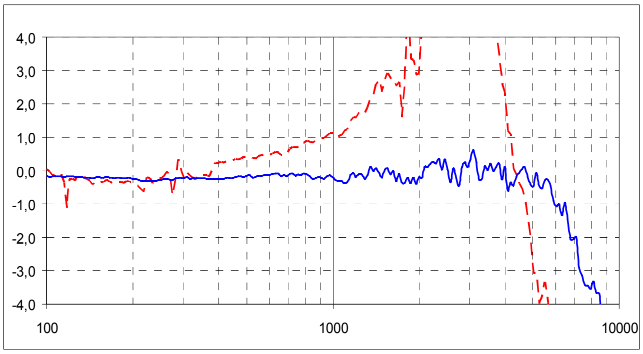

Fig. 8: corresponding frequency response

- A weighted background noise level: +3 dB
- Sensitivity @ 1 kHz: +0.5 dB
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: 1.45 dB@4 kHz

Background noise has slightly increased, but the absolute value of 21 dBA is not easy to measure under normal conditions. The increase of sensitivity shows there could be instability in the system, but the displayed value (+0.5dB change) could be linked to changes in temperature, humidity and/or barometric pressure. The frequency response is altered and reacts as an increase of mass with a resonant frequency around 3 kHz.

The multi-frequencies charge injection response shows a significant difference, clearly indicating a default in the system (mechanical change of the membrane due to the weight of the water drop).

6.3 Light dust on the membrane

Fig. 9: light dust on the membrane

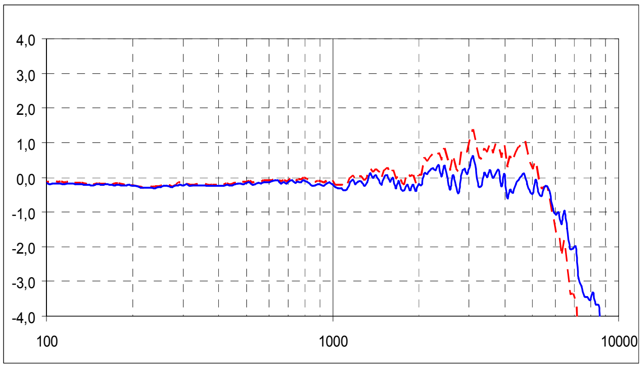

Fig. 10: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: Not significant
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: Not significant

No indicator is significant, and the frequency response does not show a significant difference either. Dust on the membrane will almost have no incidence on the measurement quality.

This experimentation shows it is better NOT to clean a microphone, to avoid any risk of damage during cleaning.

6.4 Heavy dust on the membrane

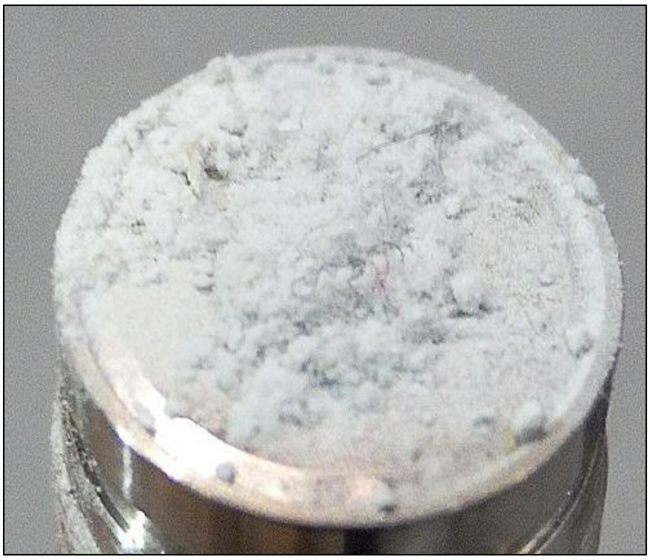

Fig. 11: heavy dust on the membrane

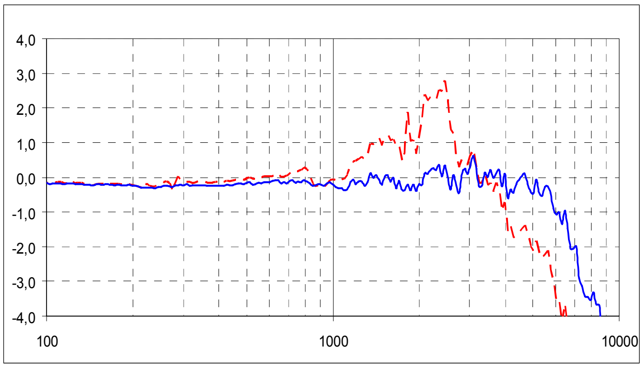

Fig. 12: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: Not significant
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: + 0.38 dB @4 kHz

This case is over the acceptable limits of dust on a membrane! The frequency response is altered and reacts as an increase of mass with a resonant frequency around 2.5 kHz.

Multi-frequencies charge injection response detects a slight difference due to the weight of dust.

6.5 Shock on the edge of the microphone

Fig.13: shock on the edge of the membrane

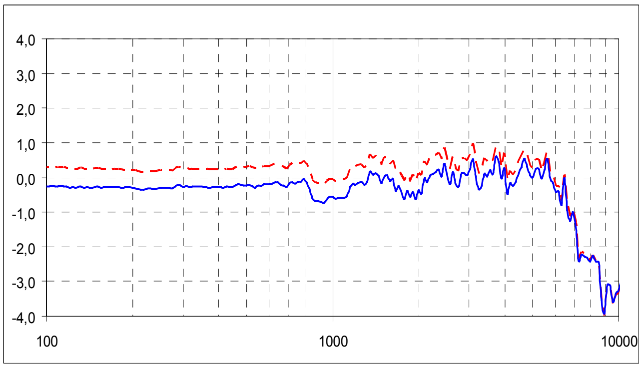

Fig. 14: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: Not significant
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: Not significant

This example is one of the most common damage of a microphone when a sound level meter is used in the field. The frequency response only shows a small increase of the sensitivity of around 0.3 dB on the whole frequency range. In fact the only consequence of this default is a lower tension of the membrane without real effect on the measurement.

Multi-frequencies charge injection response does not detect any default because the active part of the membrane is not affected.

6.6 Small cut on the edge of the microphone

Fig. 15: small cut on the edge of the microphone

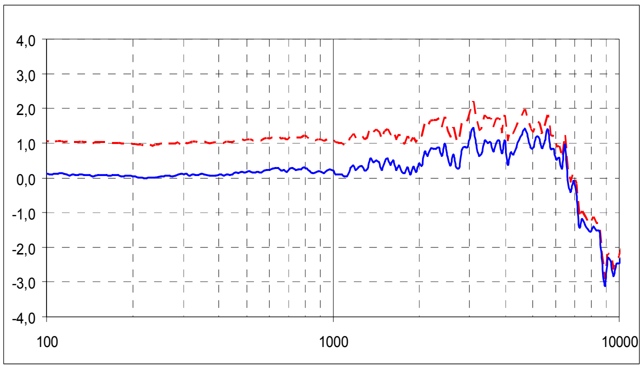

Fig. 16: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: + 1 dB
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: Not significant

The frequency response shows an increase of the sensitivity of around 1 dB on the whole frequency range. The consequence of this default is a lower tension of the membrane and is detected by the sound level calibrator.

Multi-frequencies charge injection response does not detect any default because the active part of the membrane is not affected.

6.7 Large cut on the edge of the microphone

Fig. 17: large cut on the edge of the microphone

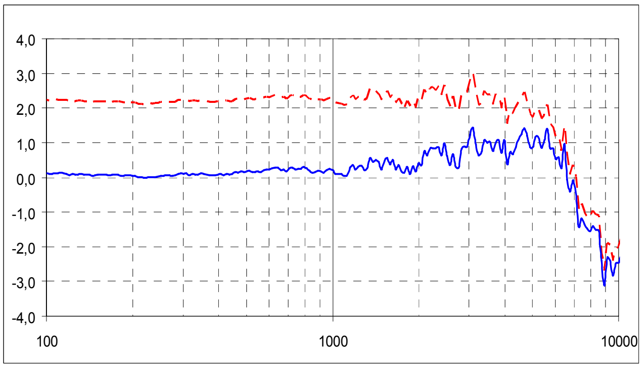

Fig. 18: corresponding frequency response

- A weighted background noise level: Not significant
- Sensitivity @ 1 kHz: + 2 dB
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: Not significant

The frequency response shows an increase of the sensitivity of around 2 dB on the low and middle frequency ranges. The consequence of this default is a lower tension of the membrane and is detected by the sound level calibrator.

Multi-frequencies charge injection response does not detect any default because the active part of the membrane is not affected.

6.8 Bad contact at the inner pin of the microphone (simulation with humid thin paper)

Fig. 19: humid paper on the inner pin of the microphone

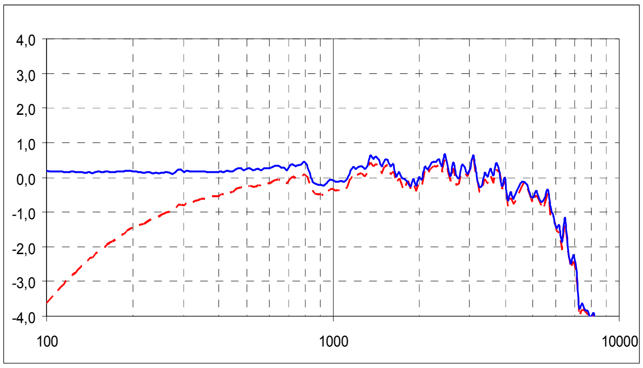

Fig. 20: corresponding frequency response

- A weighted background noise level: + 20dB
- Sensitivity @ 1 kHz: - 0.7dB
- Multi-frequencies charge injection response @ 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz: > 6 dB on all frequencies

This example illustrates a default that can happen when a sound level meter has been in use for several months without periodic maintenance. Despite the fact the connectors are gold plated, some corrosion might occur, especially if the contacts have been touched by fingers. The frequency response shows a high-pass filter effect.

The decrease of sensitivity shows there could be instability in the system, but the displayed value (-0.7 dB change) could be linked to changes in temperature, humidity and/or barometric pressure.

This default is detected by an increase of background noise and by multi-frequencies charge injection response. The impedance of the equivalent microphone has drastically changed, that explains the high sensitivity to multi-frequencies charge injection response.

7 Conclusions

The various tests performed show the usefulness of the multi-frequencies charge injection method to detect common defaults (punching of the membrane, water or dust on the membrane, bad contact). Only the cut at the edge of the membrane could not be detected by charge injection during this test because it does not create any change in the impedance of the microphone (this default can be detected by a calibration).

The choice of the five frequencies used by default (250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz) can be optimized: we recommend selecting 63 Hz, 250 Hz, 1 kHz and 4 kHz.

The maximum acceptable difference between the reference and the current measurement is to be set between 0.35 dB and 0.5 dB for an accurate detection of the defaults. For such values it is of major importance to pay attention to the stability of the high precision generator.

The charge injection being nearly equivalent to 100 dB level for a 5 V signal, the measured level may be affected by the ambient acoustic noise if the level is higher than 90 dB. It is therefore recommended to ensure the absence of noise disturbances during the test and to repeat the procedure if necessary.

The multi-frequencies charge injection method is not a calibration of the system. Its purpose is to control over time the stability of a noise measurement equipment. When performed periodically automatically and remotely (typically from one to four times a day) it will secure the validity of the measurement between two checks.

Multi-frequencies charge injection check is one of the useful tools for ensuring reliable measurements between two calibrations on unattended measurement systems.

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References

[1] IEC 61672-3 2006-10 Electroacoustics-sound level meters – part 3: Periodic tests

[2] ISO 20906:2009 Acoustics - Unattended monitoring of aircraft sound in the vicinity of airports

[3] NF S31-010 Décembre 1996 Acoustique -- Caractérisation et mesurage des bruits de l'environnement - Méthodes particulières de mesurage

[4] 01dB, a brand of ACOEM: DUO Product data sheet: NOT 1507 – December 2011