INSTRUMENTATION CORNER

Sound level meters calibration – what's it all about? Part 2

This article follows on from the one we published in the March/April 2022 issue on page 44, which discussed the wide range of calibration services on offer to support sound level meters. This article looks at the use of the associated calibrator along with the use of offsets to centre the microphone response in the permitted tolerance band.

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When submitted for a full calibration a sound level meter (SLM) should be accompanied by a sound calibrator, this should be of the make and model specified in the instrument's instruction manual.

Alternatively, it may be a suitable equivalent that has the same nominal level and frequency. The general requirement is that it should conform to BS EN IEC 60942 and have the same accuracy class as the sound level meter.

So, a class 1 calibrator is required for a class 1 sound level meter. The associated calibrator must have been independently calibrated within the previous 12 months prior to the verification of the sound level meter. The intention is that this calibrator will be provided by the user, should this not be possible, there is an option for the calibration laboratory to use one of their own. The sound calibrator is the prime traceability route to national standards and is used to determine the 'on receipt' condition of the SLM. The calibration laboratory may also have a reference calibrator that can be used as a cross check just in case there is a problem with the associated calibrator provided[1]. The initial set up of the SLM is repeated when the calibration is completed.

From this you can see if any off sets were applied before receipt for calibration and adjustments that have been made during calibration. If the difference between these initial values is significant, it may indicate problems with measurement's made with this SLM prior to the calibration.

Right: Figure 1: Extract from a typical calibration report giving the detail about the settings for the reference and associated sound calibrators as per BS EN IEC 61672-3 Ed.2 #10

1. These are the calibrator requirements specified by the manufacturer
Reference level: 94.0dB
Reference Range: 140dB FS
Reference Frequency: 1000 Hz

2. These are the results from the laboratory reference calibrator
Reference Calibrator: WSC6 - B&K-4231-1882939
Reference calibrator level: 93.93
Before calibration:
Environmental corrections: -0.02
Other corrections: -0.15
Notional level: 93.76
Calibrator level before adjustment: 93.8
After calibration:
Environmental corrections: -0.02
Other corrections: -0.15
Notional level: 93.76
Reference calibrator level after calibration: 93.8

3. This is the information and results given from the associated calibrator
Associated Calibrator: Brüel and Kjær - 4231- 3016820
Associated calibrator level: 94.10
Initial level check:
Environmental corrections: -0.02
Other corrections: -0.15
Notional level: 93.93
Indicated level: 93.9
Final level statement:
Environmental corrections after calibration: -0.02
Other corrections: -0.15
Notional level: 93.93

References

1 In a worst-case condition, the calibration data for the associated calibrator may be up to 12 months old

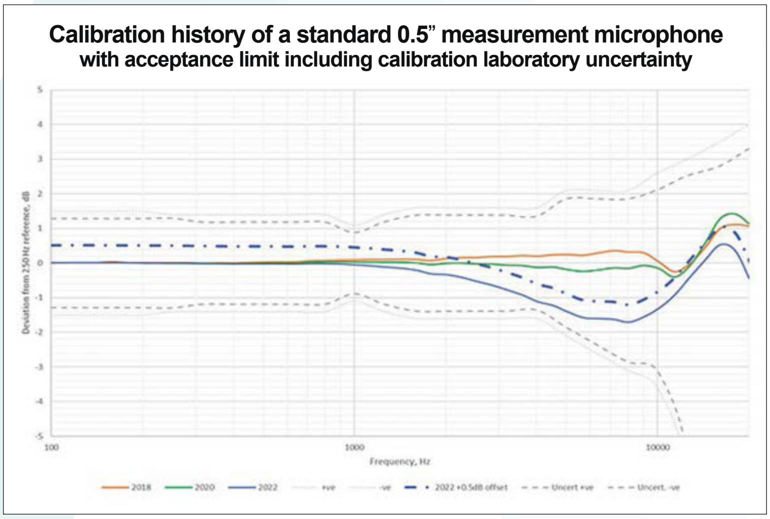
Figure 1shows a typical calibration report covering the use of the associated and reference calibrators:

1. Manufacturer's specification: The SLM manufacturer will specify the requirements for the calibrator. These are usually linked to the reference levels for the meter being calibrated.

2. Laboratory reference calibration. With modern self-compensating calibrators, the environmental corrections are not usually significant but still need to be considered. However, there are still plenty of the old-style calibrators where the environmental corrections can be significant relative to the tolerances required. Details should be in the calibrator user manual; barometric pressure corrections are usually the most significant with humidity the least. The other corrections are primarily in respect of the difference between the pressure and free field response of the microphone, these are microphone related. They can also be to take account of the volume load effect on the calibrator, particularly with non-compensating calibrators. In these cases, if the calibrator is exposed to a larger load volume, then the level produced will go down.

3. Associated calibrator results. The tasks outlined here repeat some of the above, but they then relate to the unique coupling between the SLM and its associated calibrator. As there are always some tolerances of fit and levels, these are taken care of by using the final notional level shown in this report to set up the sound level meter for each measurement project. This information is usually repeated on the final calibration certificate as the level to use for each field calibration setting. Remember, you still may need to apply environmental corrections to the result, particularly if you do not have a self-compensating sound calibrator.

As there was no difference between the before and after calibration settings this indicates that the sound level meter and calibrator have been stable prior to the calibration being performed. However, there is a difference between the levels produced by the reference and associated calibrators of 0.13dB, and as this is well within the expanded uncertainty of the two calibrators indicates all is well at the start of the calibration. At the end of the calibration the associated calibrator is reapplied to the meter and the reading noted, in this case, 93.93 dB as the value to use when the associated calibrator is used for field calibration settings. This locks the sound level meter to the reference calibrator setting and takes out any small variations due to the actual sound pressure level of the associated calibrator and any coupling artefacts associated between the microphone, calibrator and the couplers used.



Above:
Figure 2: Six-year calibration history of a half inch measurement microphone with acceptance interval

Once a different sound calibrator is used this relationship is compromised as the alternative calibrator will have a different nominal level as well as different coupling coefficients. The sound calibrator standard (BS 60942) allows a tolerance at 1kHz of between ±0.25 and ±0.4dB depending on the edition of the standard in use; hopefully there will be a calibration certificate that will give the actual level within this range with its associated uncertainty. From this information it is possible to calculate the correct level that the sound level meter should show in response to the alternative calibrator.

As soon as possible after the SLM is returned from calibration apply the alternative calibrator to the instrument and note its reading. If this correlates with what you would expect from its notional level, having taken account of expected environmental, coupling and free field corrections; then it's reasonable to use that value in future to set up the SLM.

Once the SLM has been in service for a while, things will change, as can be seen from Figure 2. Here a microphone has had a full calibration biennially over its six-year working life. The results are shown as the orange, green and blue solid lines along with the tolerances and calibration laboratory uncertainty to give an acceptance range. The first four years seem to have gone well with the drift almost within the uncertainty of the calibration laboratory. However, the last two years have seen a change in the mid-frequency range; with the 4k Hz point coming within 0.24dB of the acceptance limit for a microphone; but as we saw in Part 1, this has to be combined with the SLM's electrical and acoustic response to determine the overall performance. If these factors are constructive, it will move the result further into the acceptance limit but if they are destructive, it goes the other way.

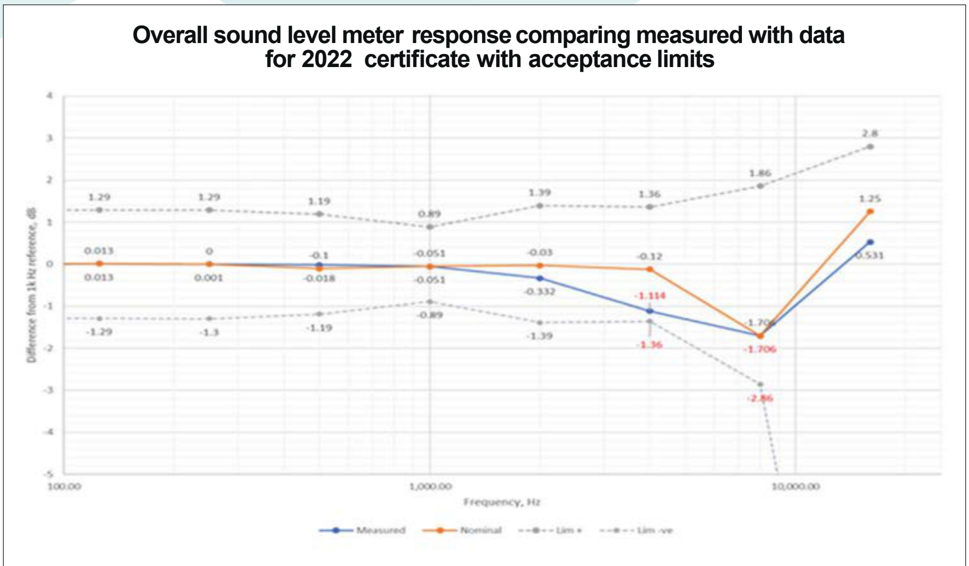
Staying with the associated calibrator situation for a while; we can see that the level at the 1kHz P42

calibration check frequency has fallen by 0.2dB over the six-year period. This will be compensated for by the recommended setting for the associated calibrator. This calibration offset helps as it has the effect of lifting the complete response curve by 0.2dB thereby giving a bit more head room over the lower limit. This is all fine when the microphone response is flat; but as we see in this case, the changes that have occurred over time are frequency specific, by 2020, the microphone has significant non-linearities in its frequency response. As a result, it will under report levels in the 2k to 10k Hz range. In these circumstances the standards[2] also allow further calibration offsets to balance the overall response in the middle of the acceptance band. So, in this case, an additional 0.5dB could be added to the recommended calibration level and this would give the response shown as the dash-dot blue curve in Figure 2. This will place the overall response nearer to the centre of the acceptance band, but we are using the tolerances in the low frequencies to keep the higher ones in specification. There are obviously plus and minus points with this procedure, and it is important that the user is aware of any such compromises made to allow a meter to pass. With class 1 instruments this is not often necessary, but the practice is more common with class 2 meters and sound level indicators, the key point is that the user must know if such offsets have been used.

In the example given here it was difficult to decide if the changes in microphone response were due to drift or damage. Having given all the facts of the case to the client, they decided to retire the microphone rather than accept a recommended six-month recalibration interval for the for the kit. Data was important in making this decision, we are looking here at 1/6th octave data as there was a complete microphone calibration included in the calibration. If just the mandated octave resolution was used as required by the sound level meter standard the situation would be as shown in Figure 3 for the 2022 data. This is shown for the two conditions mentioned in the earlier part of this series i.e. with nominal or measured acoustic data. The orange curve shows the resultant if only the nominal data method had been used. The eye would go to the 8k Hz point were there appears to be at least 1dB headroom to the limit. However, the blue curve shows the result if measured microphone data was available, here it is apparent that the problem is going to be at 4k Hz where only another 0.2dB of drift would put the microphone out of specification.

Access to the data from a full calibration report can provide all sorts of flexibility in mix and matching kit, for example the need to be able to use either high sensitivity or high frequency microphones with a sound level meter. It is not necessary to have full calibrations of the meter with each microphone, just have the alternative microphone calibrated and replace the associated microphone data with the alternative at each of the octave test points to see if it still conforms to the standard. This probably holds true with changing one half-inch microphone capsule for another but may not for a different preamplifier of different length as that could well affect the case reflection data.

Below: Figure 3: True problem masked by use of nominal acoustic data



Validity of calibration in different instrument configurations

Sometimes sound level meters have additional post measurement apps built-in, such as sound power, building acoustics, noise nuisance evaluation (BS4142)etc. These apps are post-processing the output of the sound level meter, so if the firmware algorithms they are based on are correct the results will be as good as the calibration and uncertainty of the input data from the sound level meter. These are not the 'configurations' we are considering here. As sound level meters are required to operate in many different ways to meet measurement needs so, they need to be set in suitable measurement configurations. They may at times need to operate in a handheld application whilst at others they are deployed in long term projects in exposed locations. So, size and convenience of manual control must be sacrificed to provide for the necessary weather protection, remote control and power supply requirements necessary to keep the kit running and the data flowing. In these latter cases the normal procedure is to take the handheld instrument and then add the necessary weather protection to it, and it is the acoustic effect of these front-end accessories that can impinge on the results of a full calibration, and therefore this needs to be considered when specifying the calibration of your kit. Each laboratory would have its own rules, but generally if a front-end accessory is supplied with the instrument at the time of calibration it is assumed that it will be used in the final calibration

References

2 BS EN IEC62585:2012 #8 and Annex A cover the detail about setting the optimum calibration check level. This publication is directly referenced in BS EN IEC61672 Ed2 sound level meter standards

configuration. So, if there is a windscreen or extension cable in the box it would be assumed to be part of the calibration configuration required unless you have specified otherwise[3].

We have seen earlier parts of this article that the final output of a full calibration is the sum of both the acoustic and electrical measurements along with the manual corrections for the effects of the instrument housing that were obtained during the pattern evaluation testing. The configuration described in Part 1 already accounted for the option to include a simple foam windscreen that would be used in handheld configurations. As modern sound level meters often have built in windscreen correction filters that compensate for the insertion loss of the windscreen, so then it is a simple matter to turn the filter on and off as the windscreen is added or removed. It is important to remember that the compensation provided is for that manufacturer's design of windscreen[4]. These correction characteristics would have been verified as part of the pattern evaluation, so it is reasonable to assume they are correct. If there is no compensation network for the windscreen built in, then it would be necessary to do a quick check by adding or removing the windscreen data from the summation of results table provided in the calibration report.

For longer-term measurements, or to reduce the effect of the operator holding the meter, a tripod-mounted configuration could be used. If this results in the introduction of an extension cable between the microphone/preamplifier and the SLM, then we have another configuration that will change the data that must be summed to determine conformance. As the microphone has now been removed from instrument the case reflections no longer apply. If a properly designed microphone stand has been used it is unlikely that any additional acoustic effects would have been introduced and, hence, the case reflections could be deleted from the determination of the overall response of the instrument. Usually this improves the result, but this is not always the case, so it is best to check. Note that the electrical performance may be affected by the loading provided by the extension cable; but as for both standard voltage and IEPE (constant current) microphone cables the corrections are usually negligible for cable lengths under 50 meters. Beyond this the manufacturer's specification needs to be checked for any additional corrections necessary.

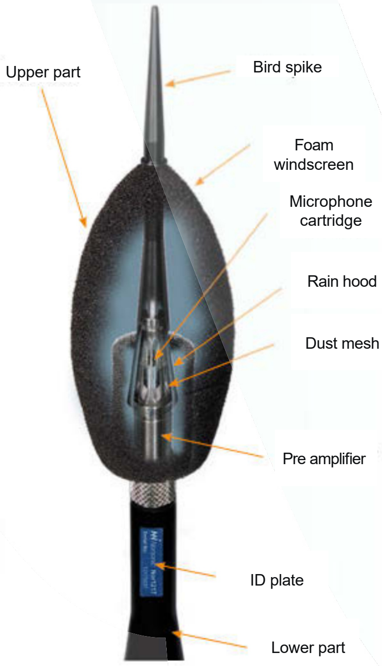


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Figure 4: Typical weather protection for class 1 measurement microphone system

So much for simple systems, but once we consider permanent outdoor installations more elaborate weather protection is required, mostly to keep the rain and detritus out of the microphone; to do this the microphone has to be orientated vertically. A typical arrangement is shown in Figure 4, where in addition to a larger foam windscreen, there are both rain and dust covers around the microphone as well as bird spikes etc to keep the vermin out; these must be carefully designed to make them as acoustically transparent as possible. These solutions tend to fall into two types; firstly, there are those that are complete integrated plug and play systems with integrated microphone and preamplifier; whilst the other group are retrofit kits that allow the use of the existing microphone and preamplifier from the SLM.

At this point we need to consider the polar response of the microphone and the effects rotating by 90° will have. A handheld sound level meter is normally designed to have the microphone pointed at the sound source; hence sound arrives horizontally with an incidence angle of 0° to the diaphragm. Rotating it by 90° will cause the sound to arrive at a grazing incidence to the diaphragm; in doing this its frequency response at higher frequencies will be progressively reduced as the frequency increases reaching to around -10dB at 20k Hz. The complete integrated systems can have a microphone that is designed to give the correct acoustic response when it is mounted vertically, i.e., with the sound arriving at grazing (90°) incidence to the microphone diaphragm. This would give the correct response for sources that are co-planar with the horizon, such as traffic noise, but for aircraft noise a 0° incidence would be required, so be sure of the type of incidence the device selected has. These integrated weather protected microphones normally must be calibrated as a complete assembly in an acoustic chamber and the results of those tests combined with the other data in the meter's periodic verification as though it were an alternative microphone. Some of these systems allow the microphone capsule to be removed and calibrated separately and, in these cases, the correction data to compensate for the insertion of the weather and vermin protection would need to be available[4] to confirm that the complete assembly still meets the specification.

In respect of the retrofit kits, they will have to use the microphone supplied with the SLM which would normally have been designed to respond to noise propagating horizontally (0°), which must therefore be rotated by 90° to allow the weather protection to work. Correction data needs to be available to compensate for this realignment. P44

References

3 If correction filters are provided, they are normally assumed to be correct making the windscreen acoustically transparent

4 For Edition 2 meters this information will need to be in the format required by BS 62585:2012

Again, if all the kit comes from the same manufacturer it is also possible to include correction filters to the SLM's response so that direct readings of weighted sound level can be made. In addition to the angle of incidence correction, we must consider the effects of the weather protection, so there is a separate set of corrections needed for these as well.

Bear in mind the data provided by the manufacturer of the weather protection system will probably be based on the premise the microphone had the 'nominal' response; during the calibration the actual performance of the microphone will be obtained and the insertion effects of the weather protection will be added to this actual, and not the nominal, response.

The data in figure 5 shows the effect of simple foam ball windscreens as the red and yellow curves for both the 90 mm and 60 mm sizes of 35 ppi windscreens. The trade-off here is the bigger the ball the higher the attenuation of wind noise but the bigger the insertion effects on the microphone performance. The curve also shows error bars for the expanded uncertainty with which the data was obtained, with these devices this is very low. The blue and green curves show results for a typical retrofit weather protection system representing the vertical and horizontal incidence of the sound. Here you can see that the corrections are larger than for the simple foam balls as well as having higher uncertainties associated with them. Those for the horizontal incidence include the angle of incidence effect and hence corrections are much larger and also have more significant uncertainties associated with them.

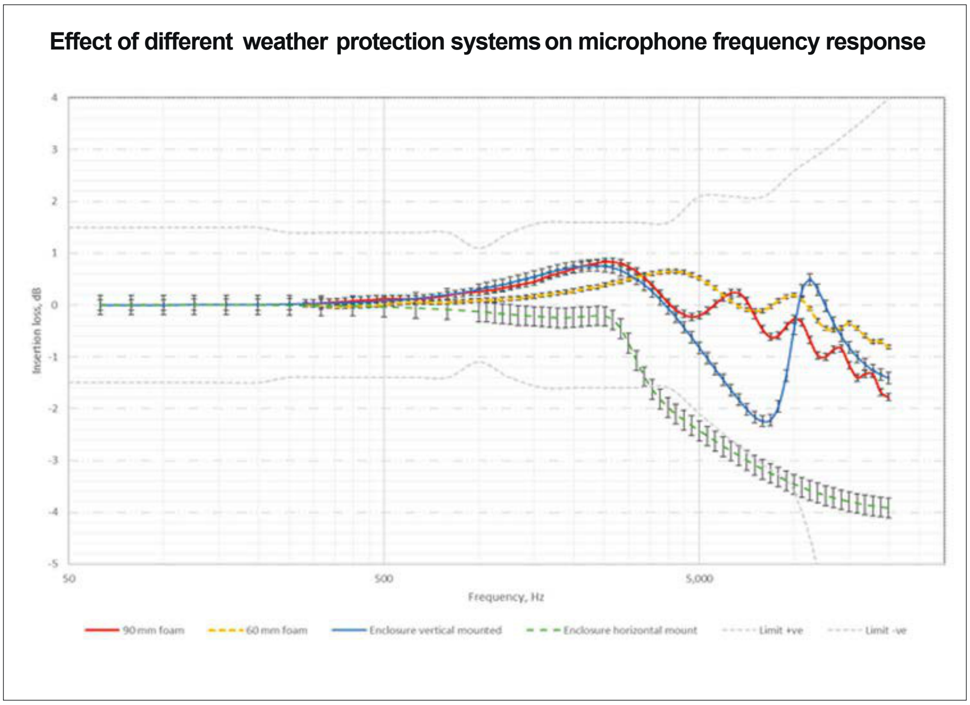

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Figure 5: Windshield comparisons with uncertainties. Foam ball types of different sizes and retrofit weather protection systems with different incidence angles