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

We are all used to the idea that sound level meters (SLMs)need calibration, ranging from the simple field calibration checks before and after each measurement project through to routine calibration in an external laboratory. Just as there is a wide selection of sound level meters available there are a wide range of calibration services on offer to support them.

By Ian Campbell, Technical Director at Campbell Associates Ltd.

It may not be practical to calibrate devices such as mobile phone apps, while simple sound level indicators could not justify on cost grounds anything more than a simple acoustic check at a couple of frequencies or levels.

At the other extreme professional SLMs require comprehensive tests covering the full range of functions and environments over which the instrument is designed to perform to specification. So, the user is presented with a range of options from a simple check calibration on a sound level indicator to a full statement of conformance to a published specification as required for legal metrology applications.

In this series of Instrumentation Corner articles, we will look at the various options available in the types of calibration service on offer. This will include going into more detail on the choices the user has in specifying how and what needs to be done to ensure their instruments are giving all the information at the level of precision they require. In addition, there is the need to provide the necessary data to include in their measurement's uncertainty budget.

The articles will cover the decision between calibration and conformance, the use of nominal data in calibrations, the use of associated sound calibrators and offsets as well as the instrument configuration during calibration.

Part 1: 'Calibration' or 'conformance

We are concerned here with what is required and how individual laboratories set about meeting those needs.

There is no doubt that 'noise' is a problem in society and, as a result, a wide range of rules and regulations to control the acoustic environment has built up.

It follows that before you can control noise, you must be able to measure it to defined standards of accuracy; enabling limits to be set and enforcement procedures put in place. Hence, we enter the field of legal metrology.

There are, however, other areas of professional practice where high levels of accuracy are needed but the conformance and verification requirements are less demanding; as well as measurement tasks where lower standards of detail and precision may be acceptable. For these applications the controlling standard is BS EN IEC 61672:2013 with type approved class 1precision instruments for legal metrology applications through to class 2 general purpose sound level meters. Below these there are other applications where just relative measurements are required, for example, setting up a domestic hi-fi system. This last case is the area covered by sound level indicators and, as there are no generally recognised specifications for these, each manufacturer publishes their own.

Unfortunately, there are many examples of these low-cost instruments being offered for sale as sound level meters and many even quote the BS standard number. The technical aspects of these matters were investigated by a recent Institute of Acoustics Measurement and Instrumentation Group project that tested several different models of sound level indicators marketed in the UK that were all claimed to meet the BS EN IEC 61672 standard.

They all failed to do so – often quite spectacularly.

Buyer beware

So, we have instrumentation costing from a hundred pounds or so to many thousands and the buyer must ensure that the calibration service offered meets their requirements.

For most applications, we are trying, directly or indirectly, to quantify the human reaction to sound. This means we must deal with the very wide dynamic and frequency range of human hearing as well as taking account of the time history of the subjective noise.

So basically, we need a measurement microphone and some electronics that display the sound numerically. The electronics can be quite complex and are designed take care of the non-linearity of the subjective reaction to noise in terms of both level and frequency. In addition, it must provide the necessary time history analysis to take care of very short transient sounds as well as to provide long-term time history indices. It follows the electronics must be provided with an output from a microphone that is always correct and stable. Sound pressure level changes can be very small and hence microphones are delicate, they are also affected by changes in temperature, humidity and barometric pressure; so are often seen as the weak link. Unfortunately, acoustic testing is the expensive part of the verification of the meter's accuracy, and is the area where compromises are often made on cost grounds.

Test results

To keep the costs of calibration as low as possible the usual procedure is to make as many of the tests as possible using electrical signals injected into the sound level meter via a dummy microphone. These results then must be corrected to take account of both the performance of the microphone and the acoustic effects of the instrument in the sound field. It follows that the instrument must have the necessary test points to inject these signals and allow for the separate acoustic testing of the microphone. Most sound level indicators do not provide these facilities; hence, it becomes necessary to test the complete instrument in an anechoic chamber. This is usually ruled out on cost grounds.

The only practical alternative is to use a multi-frequency and multi-level sound calibrator. Apart from limiting the verification to just a few points it provides the pressure response of the sound level indicator when it is required to show the free field sound level. So, the calibration laboratory will need to determine the corrections to apply. This normally means measuring a number of the microphones of the type used in the meter in a free field room, again, difficult on cost grounds.

These corrections can be large, relative to the tolerances, at high frequencies. So, if the calibration documentation states that a sound calibrator was used, it is necessary to check the pressure to free field corrections have been applied. These should also have associated uncertainty values with them. If the corrections are not available, the basic sensitivity should be set against a 250 Hz calibrator and any higher frequency data just used for drift considerations. This represents the simplest form of calibration on offer from laboratories and, in fact, does not represent much more than a simple pre-measurement field calibration check. But that is what you get for a £55 'calibration'.

Performance and tolerances

As far as legal metrology applications are concerned the measurements must be accurate and traceable to primary standards as well as being stable with both time and environment. To ensure compatibility of competing sound level meters, a set of three British and International standards (BS EN IEC 61672 series) have been developed to ensure that the legal process can concern itself with the merits of any individual case and not become diverted into debating the accuracy of the measurement instrumentation.

The primary requirement of the standard is to specify the performance of the instrument and the tolerances that should apply; this is all covered in part 1of the standard. The second part defines a series of type approval tests (known as 'pattern evaluation' in the standard) for each model put onto the market. This is the responsibility of the manufacturer who must contract with an independent national laboratory to test the instrument for conformance with the specification; normally three samples of each model are submitted for testing. These tests cover all aspects of the performance, including detailed acoustic, electromagnetic compatibility and electrical testing of the complete instrument as well as a full range of temperature, humidity, and barometric pressure tests.

In addition, from the detailed acoustic testing, a series of corrections are derived to allow subsequent electrical tests to be corrected for the acoustic effects of the instrument case, windscreen, or other front-end accessories, to reflect the overall performance of the instrument in the sound field. All this work makes the final stage of ('periodic verification', which is covered by part 3 of the standard) much quicker and therefore less expensive.

Calibration schedule

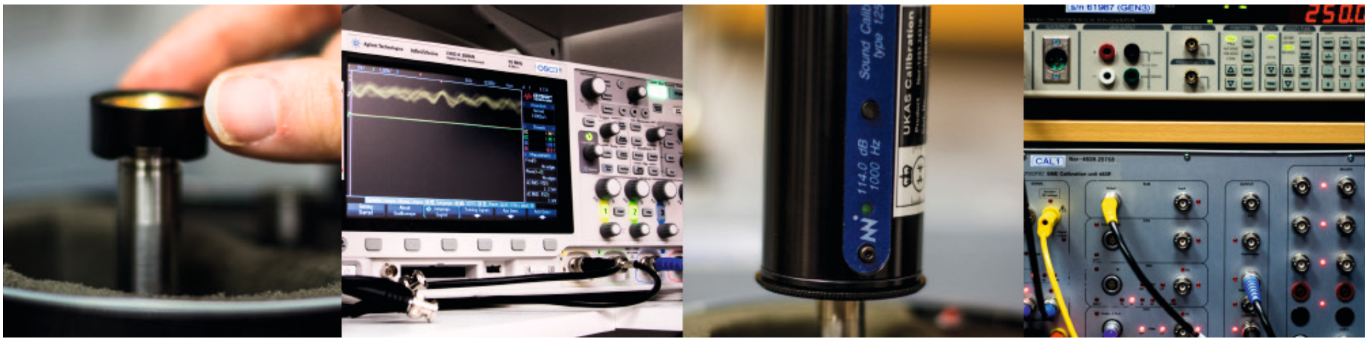
This biennial routine calibration is the responsibility of the user who must contract with an appropriate laboratory to have the work carried out. So, having identified the parameters that are likely to drift or be damaged, the number of tests necessary can be minimised. Furthermore, by use of the correction data derived from the pattern evaluation the number of expensive acoustic tests can also be minimised; and yet the results will still reflect the overall performance of the meter. To make all this happen the standard requires that all the necessary test points are provided in the instrument and that the necessary correction data is made available to the user and the accredited calibration laboratories.

So, we have a comprehensive audited procedure to determine compliance with the standard, as that is exactly what the noise control regulations require, i.e. the meter should comply with BS EN IEC 61672[1] . So, if a meter has undergone part 2 'pattern evaluation' at an independent national laboratory and has completed the part 3 'periodic verification' at an accredited calibration laboratory, where the uncertainties of the results are below the required maximum, then the instrument is deemed to comply with the standard.

A certificate of 'Calibration and Conformance' may then be issued in accordance with legal metrology requirements. The statement of conformance on the accredited certificate will state full conformance or detail the reasons why it cannot be confirmed, such as failure of the part 3 tests or no evidence of part 2 pattern evaluation. P46

References

1 BS 61672 has a comprehensive statement of what is necessary to confirm compliance. Other standards or specifications do not always have this information and it is necessary for the calibration client and laboratory to agree the testing that is required and the decision rules to be used to confirm compliance.



Above: Figure 1
Conformance to the Standard is confirmed when all requirements are met. This entails combining acoustic and electrical test results with reference data provided by the manufacturer from pattern evaluation testing

The maximum uncertainties mentioned above are given in the standard. The accreditation authority, United Kingdom Accreditation Service (UKAS)in the UK, will ensure these are maintained as well as exercising a quality control audit programme covering the accredited calibration laboratories' activities. Some laboratories also issue 'traceable' certificates covering both calibration and conformance. As these do not incur the oversight and verification of the accreditation authority, they are usually less expensive. They may not, however be accepted as evidence in legal or commercial disputes.

Testing options

To meet the needs of those users who do not require the full legal metrology status but still need to know the degree of precision their meters are delivering have other options. Naturally the non-accredited route mentioned above is one possibility. Any laboratory or supplier quoting BS EN IEC 61672-3 as the calibration standard should be aware that it requires that all the specified tests must be carried out.

We have seen in specifications statements such as: "frequency response per BS 61672 class 2", that may well be so, but what about the rest of the specification? It would still need to be calibrated to verify the claim. If, for example, you never need to measure peak levels, then you could dispense with that test by specifying a meter that does not have that function as the standard only requires you to calibrate features provided. So, in some circumstances it is possible to have an edited series of tests to reduce the cost of the calibration. But care is needed to ensure those using the results are aware of the limitations such a procedure would introduce.

In conclusion, the 'Full Monty' is the accredited certificate of calibration and conformance. For those situations where that level of QA and compliance is not necessary there are other options. These need to be evaluated with care to ensure that they are providing the required information.

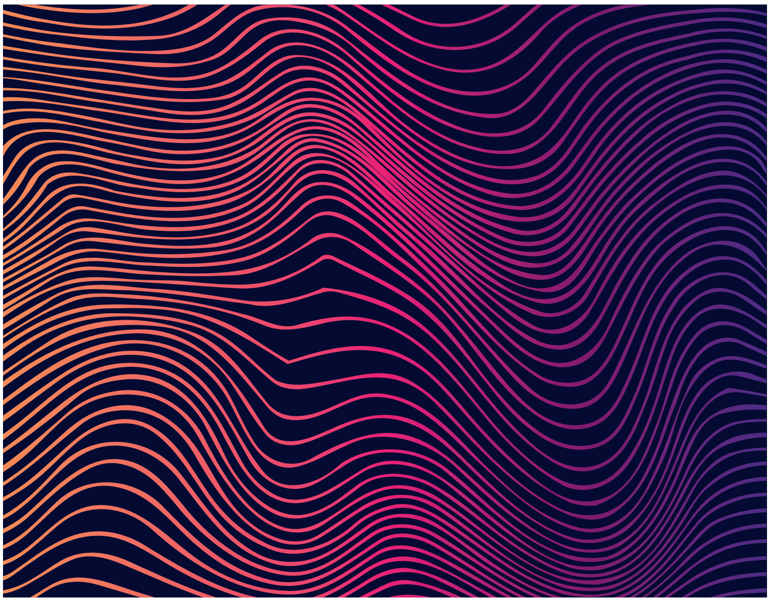
Part 2: Use of nominal microphone data

As part of the periodic verification of a sound level meter the standard requires that the overall performance of a class 1sound level meter should be determined at octave band centre frequencies from 63 to 16kHz for each of the weighting networks provided. To do this for each individual instrument in an anechoic chamber would be prohibitively expensive. So, the usual procedure is to make acoustic tests on the bench and then correct them for the acoustic effects of the case and other front-end accessories.

This requires four sets of data to be combined:

1. electrical test of the frequency weighting networks undertaken by the calibration laboratory;
2. acoustic tests on the microphone undertaken by the calibration laboratory;
3. corrections to account for case reflections and defraction around the microphone from data provided from pattern evaluation testing; and
4. effects of weather protection provided by the manufacturer or measured by the calibration laboratory.

Each element comprises the deviation from the target response required by the standard (in dB) and the expanded uncertainty (dB, k=2) with which this result was obtained. Combining these individual elements will show how the complete instrument will perform in an actual sound field. This result can then be compared to the acceptance interval and uncertainty. P48



requirements given in the standard for the complete instrument; thereby allowing a pass/fail decision to be made.

A typical presentation of this data is shown in Figure 2 below.

The upper part shows the assessment using the actual microphone response extracted from a full microphone calibration. As such, a microphone calibration is an expensive undertaking. The standard allows, in certain circumstances, for the acoustic tests to be limited to just 125, 1k and 8k Hz and for 'nominal data' to be used for the other six octave band values.

In the lower table the real values have been replaced by the manufacturer's nominal data along with its uncertainty. Fortunately, in this case they both pass, but with different data and uncertainty calculations.

Combined response for BS 61672 Ed2 meter for A weighted response with measured microphone response

Frequency Hz	SLM Electrical5Microphone5Case reflection						Weather protection		Comb. Uncert.	Data Limit5Deviation		Decision
	Meas.5U5dB5U5dB5U5dB5U											
	dB5dB5dB5dB5dB5dB5dB5dB5dB											
6350		0.1	0	0.1	0	0.1	0	0.1	0.20555555555555555± 1505Pass			
12550		0.1	0	0.1	0	0.1	0	0.1	0.20555555555555555± 1505Pass			
250	-0.150.1		0	0.1	0	0.1	0	0.1	0.205± 1		-0.1	Pass
500	-0.150.150.150.150.150.1						0	0.1	0.205± 1		-0.1	Pass
1,00050		0.150.150.150.150.150.1							0.205± 0.7		0.1	Pass
2,00050		0.150.150.1			-0.3	0.1	0.4	0.1	0.20555555555555555± 1505Pass			
4,000	-0.150.1		-0.2	0.2	-0.150.1		0.7	0.1	0.265± 1		0.3	Pass
8,00050		0.1	0	0.2	0.1	0.2	0.1	0.2	0.365+1.5,-2.5		0.2	Pass
16,00050		0.1	0.650.350.250.2				-0.5	0.3	0.485+ 2.5, -16		0.3	Pass

Data source key

(green)	Measured	(blue)	Supplied by manufacturer	(orange)	Actual microphone response

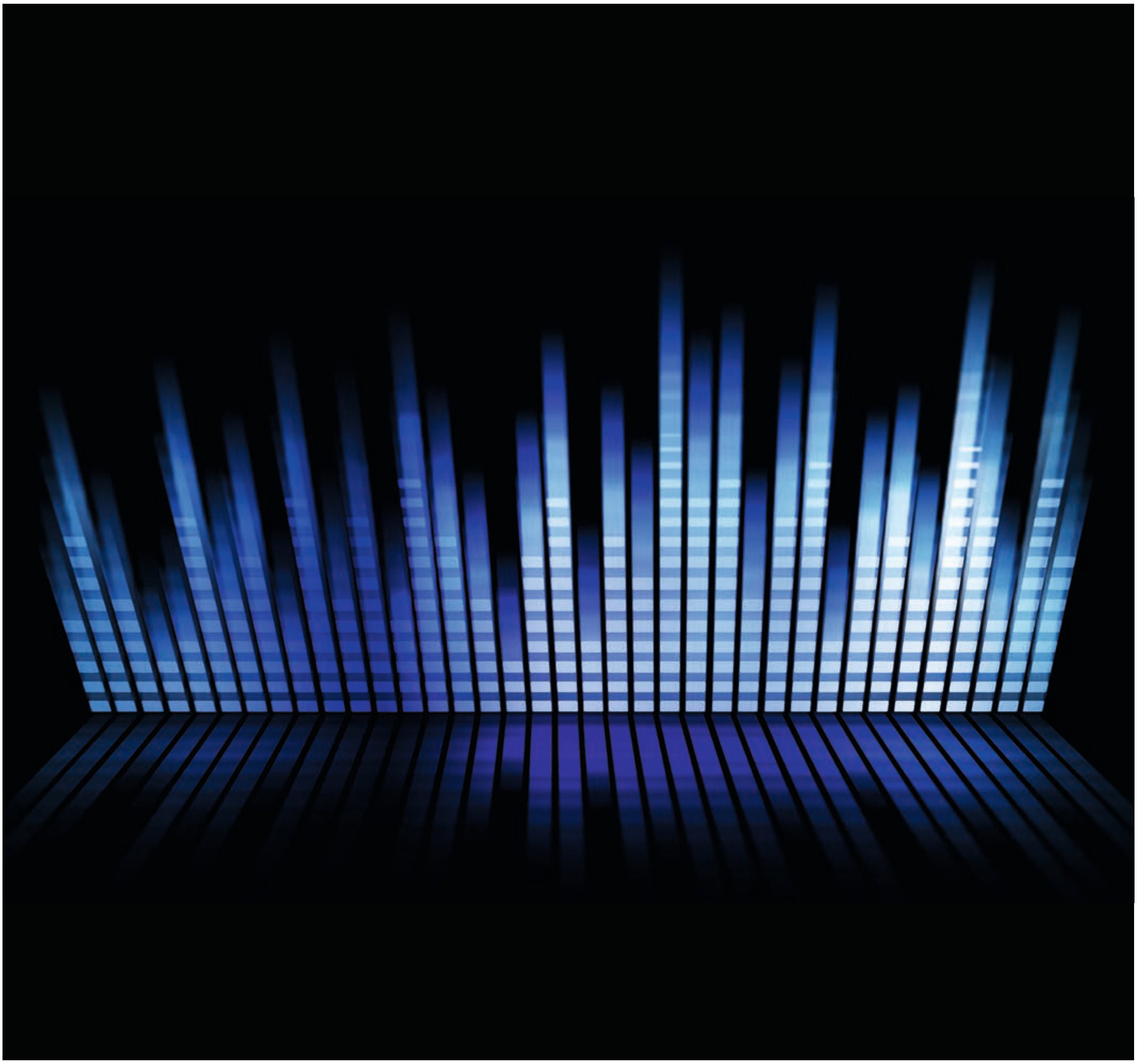
Combined response for BS 61672 Ed2 meter for A weighted response with nominal microphone data

Frequency Hz	SLM Electrical5Microphone5Case reflection						Weather protection		Comb. Uncert.	Data Limit5Deviation		Decision
	Meas.5U5dB5U5dB5U5dB5U											
	dB5dB5dB5dB5dB5dB5dB5dB5dB											
6350		0.1	050.2555555555555550			0.1	0	0.1	0.305± 1505Pass			
12550		0.1	0	0.1	0	0.1	0	0.1	0.20555555555555555± 1505Pass			
250	-0.150.1		050.2555555555555550			0.1	0	0.1	0.305± 1		-0.1	Pass
500	-0.150.150.1			0.25	0.150.1		0	0.1	0.305± 1		-0.1	Pass
1,00050		0.1	0.01	0.150.150.150.150.1					0.205± 0.750.215Pass			
2,00050		0.1	-0.0350.255-0.3			0.1	0.4	0.1	0.30555555555555555± 15555555555555550.0755555555555555			
4,000	-0.150.1		-0.1250.25		-0.150.1		0.7	0.1	0.30555555555555555± 15555555555555550.385Pass			
8,00050		0.1	0.450.2		0.1	0.2	0.1	0.2	0.365+1.5,-2.5		0.6	Pass
16,00050		0.1	1.2550.45		0.250.2		-0.5	0.3	0.595+ 2.5, -1650.955Pass			

Data source key

(green)	Measured	(blue)	Supplied by manufacturer	(red)	Nominal microphone data

Above: Figure 2
Typical summation of individual elements of the calibration to get the overall response of the meter using either actual or nominal data



The electrical and acoustic tests on the sound level meter are performed by the calibration laboratory, while the case reflections and windscreen data are provided from the pattern evaluation. In respect of the microphone data, if a full microphone calibration has not been performed there is the option to use a comparison coupler or an electrostatic actuator to make bench measurements of the microphone response at the other six octave centres.

There is a further option for just the results at 125, 1kand 8k Hz to be made acoustically with the other six octaves reported as nominal values. This will allow the three mandated acoustic tests to be measured with a standard multi-frequency sound calibrator, this would be a lower cost option for the laboratory. This nominal data can be provided by the manufacturer or determined by the calibration laboratory.

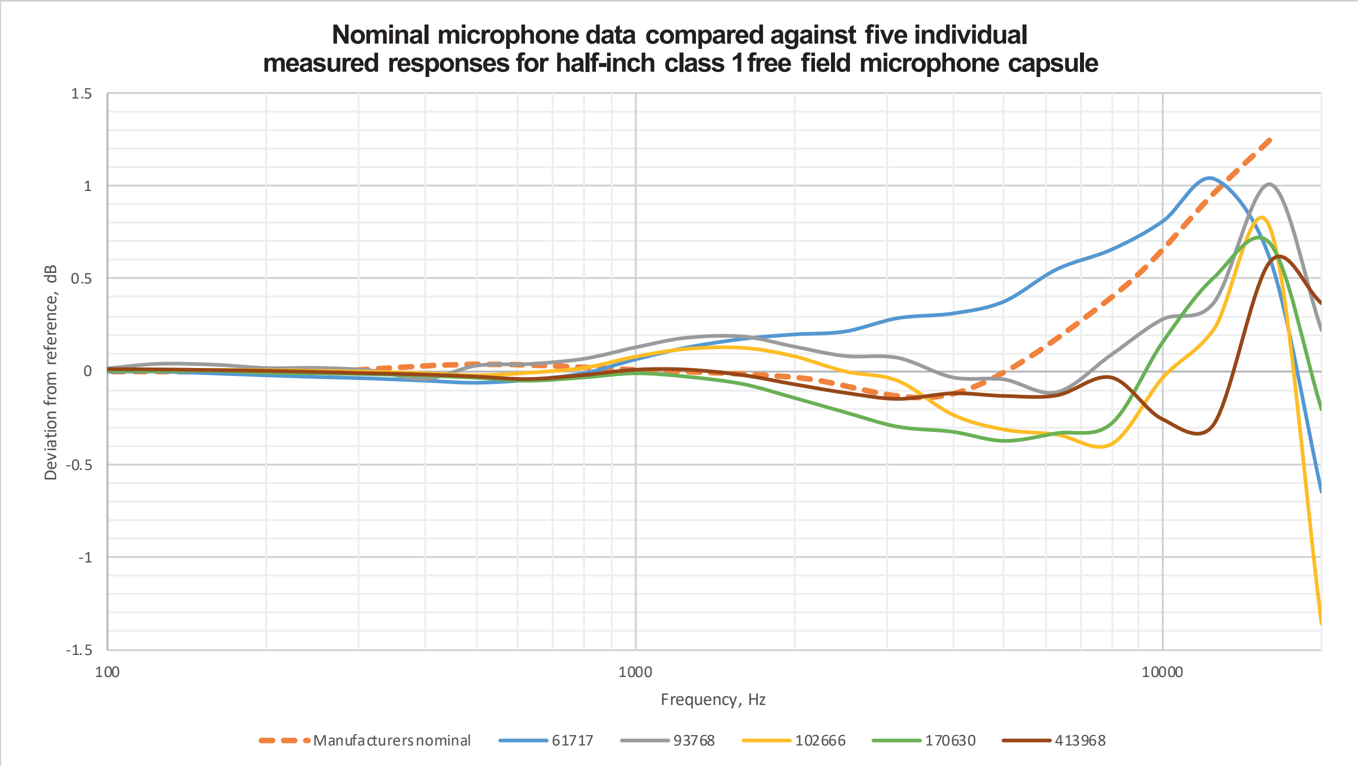
The procedures here vary between the original 2006 (Edition 1)version of the standard and the revised 2013 (Edition 2) versions. For Edition 1instruments, the nominal data should be provided by the manufacturer along with uncertainties. But for Edition 2 meters, the standard requires these six additional octave band points to be measured by the calibration laboratory, only if they cannot be measured may nominal values be used.

If the laboratory has to use this concession, then the nominal data must be determined as specified in BS EN 62585:2012. This requires measurements to be made on at least five samples of the microphone to determine the nominal responses along with their associated uncertainty. The results therefore need to be qualified by a statement of either:

1. The actual frequency response of microphone (manufacturer, model and serial number) has been used for the calculations to confirm compliance with BS EN IEC 61672-3 for a class 1meter, or

2. Nominal frequency responses determined as per BS EN 62585-2012 have been used for the calculations to confirm compliance with BS EN IEC 61672-3 for a class 1meter.5

P50



Above: Figure 3
Nominal microphone response with actual response of five randomly selected microphones of the same type

It is possible therefore for a calibration and conformance certification to only require acoustic calibration at three frequencies with the others based on estimated data. If, however, the laboratory includes a full calibration of the microphone as part of their calibration procedure then it is a simple matter to include actual measured data in the computation of the complete instrument; this will reduce the overall uncertainty of the results to be included in your projects.

In the case of nominal results being used, it would be advisable for the user of the instrument to keep a close eye on the 8k Hz result to detect any changes that may be symptomatic of movements in the microphone response at other frequencies that would not be reflected when using nominal results.

In the example above, comparing the nominal response with five randomly selected samples of the same type of microphone, we see differences over the samples of 1.1dBat 8k Hz and with a maximum difference of 0.8 dB between the nominal and the samples. All of this is within the requirements of the standard, but use of nominal data does require the user to make some technical assessments on how the microphone may well be performing.

If you have an Edition 1meter, the decision regarding the use of nominal or measured microphone responses is at the discretion of the user or the calibration laboratory. However, with Edition 2 meters; it states that measured data will be used, unless it cannot be measured. Not quite so clear here as to what that means: laboratory does not have the facility, or it does but the client thinks it is too expensive, etc.?

In the next issue

The next contribution to this series of notes (May/June 2022 issue) will look at the use of the associated calibrator along with the use of offsets to centre the microphone response in the permitted tolerance band. That will give still more food for thought about the use of nominal microphone performance.