AFRIMETS.AUV.A-S2

FINAL REPORT

22 March 2023

Summary

Results of Regional Metrology Organisation supplementary comparison AFRIMETS.AUV.A-S2 concerning the calibration of a Brüel & Kjær 4226 multi-frequency sound calibrator are reported here. Sound pressure level results at frequencies from 31,5 Hz to 16 kHz and nominal sound level settings of 94 dB and 114 dB, were evaluated for consistency, the calculated comparison reference values and Degrees of Equivalence are reported here. The comparison's purpose was to prove technical capabilities supporting the submissions of Calibration Measurement Capabilities in the BIPM Key Comparison Data Base. *The Light Shines* quite far, the new Calibration Measurement Capabilities that may result from this work, underpin some important fundamental acoustic calibration services, e.g., sound calibrators, sound level meters and personal sound exposure meters. These instruments are intrinsic to the effective monitoring and implementation worldwide of human hearing conservation and hearing loss assessment programs, all which impacts quality of life. According to the World Health Organization, nearly 1,5 billion people experience some decline in their hearing capacity during their live [1].

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1. INTRODUCTION

This is the AFRIMETS.AUV.A-S2 regional Supplementary Comparison (SC) Final Report as performed under the auspices of the AFRIMETS Technical Committee for Acoustics, Ultrasound and Vibration (AUV). The comparison was undertaken to address the needs from the participating NMIs of two Regional Metrology Organisations (RMOs) for establishing and maintaining measurement equivalence, as afforded by the CIPM Mutual Recognition Arrangement.

This report is in support of the participating NMIs CMC submissions for multi-frequency sound calibrators, known as service category identifier 2.2.1 in the Classification of Services in Acoustics, Ultrasound and Vibration [2].

The AFRIMETS.AUV.A-S2 SC measurement phase started in July 2018 and was concluded in March 2020. The sound pressure levels, frequencies and total distortion + noise were required to be determined in accordance with IEC 60942: 2017 [3]. Comparison Reference Values (CRVs) and Degrees of Equivalence (DoE) were determined only for sound pressure level results at 94 dB and 114 dB sound level settings.

Five National Metrology Institutes (NMIs) from two different RMOs participated in this comparison i.e., NMISA (AFRIMETS), GUM (EURAMET), NIS (AFRIMETS), KEBS (AFRIMETS) and VTT MIKES (EURAMET).

This report contains the following information relating to the participating NMIs: description of measurement method, measurement results, measurement uncertainties. Results and uncertainties were also evaluated in accordance with IEC 60942: 2017 Annex B - Periodic tests.

2. TECHNICAL PROTOCOL

The comparison Technical Protocol [4] was approved by the CCAUV Key Comparison Working Group (KCWG) and was subsequently published in the BIPM Key Comparison Database (KCDB) in accordance with CIPM MRA-G-11 − Measurement comparisons in the CIPM MRA [5].

This comparison was only concerned with the calibration of a multi-frequency sound calibrator according to IEC 60942: 2017, using a Laboratory Standard ½” Pressure (LS2P) reference microphone [6].

The parameters to be calibrated were 94 dB and 114 dB sound pressure levels, frequency and total distortion plus noise (TD+N), as indicated in Table 1. The reported sound pressure levels were required to be corrected to reference environmental conditions.

Multi-frequency sound calibrator, Brüel & Kjær 4226 s/n: 3003604, was circulated between all participants as the comparison artefact.

Table 1. Parameters that were required to be determined and reported

Nominal frequency (Hz)	Parameters determined for 94 dB and 114 dB level settings		
	L_p (dB relative 20 µPa)	Measured frequency (Hz)	TD+N (%)
31,5	x	x	x
63	x	x	x
125	x	x	x
250	x	x	x
500	x	x	x
1 000	x	x	x
2 000	x	x	x
4 000	x	x	x
8 000	x	x	x*
12 500	x	x	x*
16 000	x	x	x*

*The band pass filter requirements of IEC 60942: 2017 affect the measurable number of harmonics.

Circulation of the comparison artefact and the comparison measurements were performed from July 2018 to March 2020.

3. PARTICIPANTS

The following National Metrology Institutes (NMIs) participated in this comparison:

- National Metrology Institute of South Africa (NMISA), South Africa (Pilot)
- Central Office of Measures (GUM), Poland
- National Institute of Standard Egypt (NIS), Egypt
- Kenya Bureau of Standards (KEBS), Kenya
- VTT Technical Research Centre of Finland Ltd, Centre for Metrology MIKES (VTT MIKES), Finland

4. METHODS

Although the IEC 60942: 2017 edition was specified as the basis according to which the results were to be obtained, variations are to be expected due to varying factors and different approaches to the implementation of the document standard. However, the Brüel & Kjær 4226 could only be calibrated using a LS2P microphone.

Descriptions of each participant’s system and calibration method employed are captured in Annex A.

5. ARTEFACT STABILITY

The stability of the Brüel & Kjær 4226 s/n: 3003604 comparison artefact was monitored throughout the measurement phase of the comparison.

Circulation pattern chosen for this comparison was a hybrid-star configuration in which the pilot NMI performed its measurements first, the comparison artefact was then circulated to the participating NMIs, after which it was returned to the pilot NMI for stability measurements.

The Brüel & Kjær 4226 was stable during the measurement phase of the comparison as illustrated in Figures 1 and 2.

Figure 1 illustrates all the sound pressure level stability measurements as the deviation from the mean of all stability results for 94 dB (left) and 114 dB (right) settings. Figure 2 illustrates only the sound pressure level stability measurements results at 1 kHz over time as the deviation from the first measurement for 94 dB (left) and 114 dB (right) settings. The blue regions are the pilot's uncertainties (k = 2).

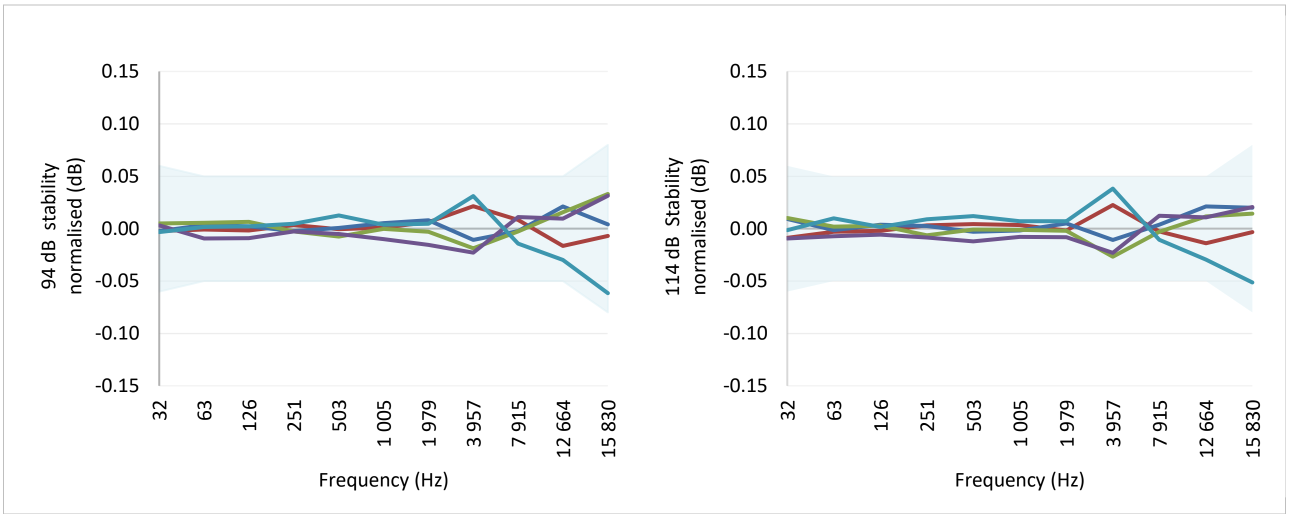


Figure 1. Normalised sound pressure level stability results (94 dB left and 114 dB right).

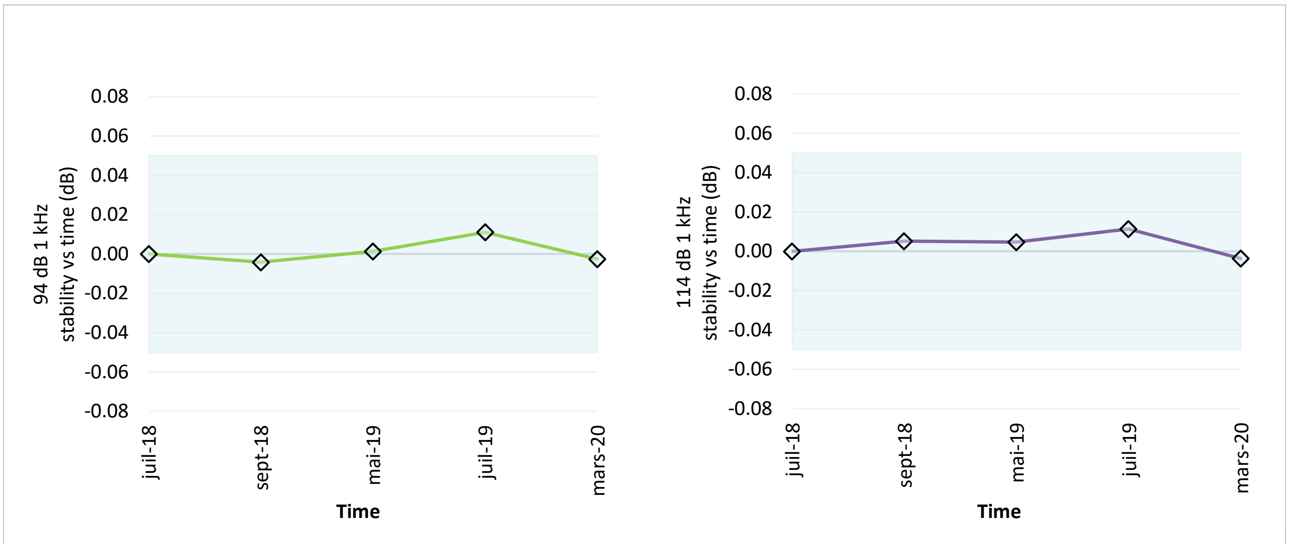


Figure 2. Stability sound pressure level results at 1 kHz over time (94 dB left and 114 dB right).

6. PARTICIPANTS RESULTS

All NMIs reported their results utilising their standard certificate formats and by completing and submitting a provided reporting template. Only the results as reported in the completed reporting templates were used for calculations and reporting purposes of this comparison.

Annexes B and C reports on all the participants' results and their uncertainty matrixes. Annex D reports on all sound pressure level, frequency and distortion results as evaluated in accordance with IEC 60942: 2017 for acceptance limits and maximum-permitted uncertainty of measurement.

Figure 3 displays all participants' sound pressure level results as received prior to analysis, for 94 dB and 114 dB sound pressure level settings respectively.

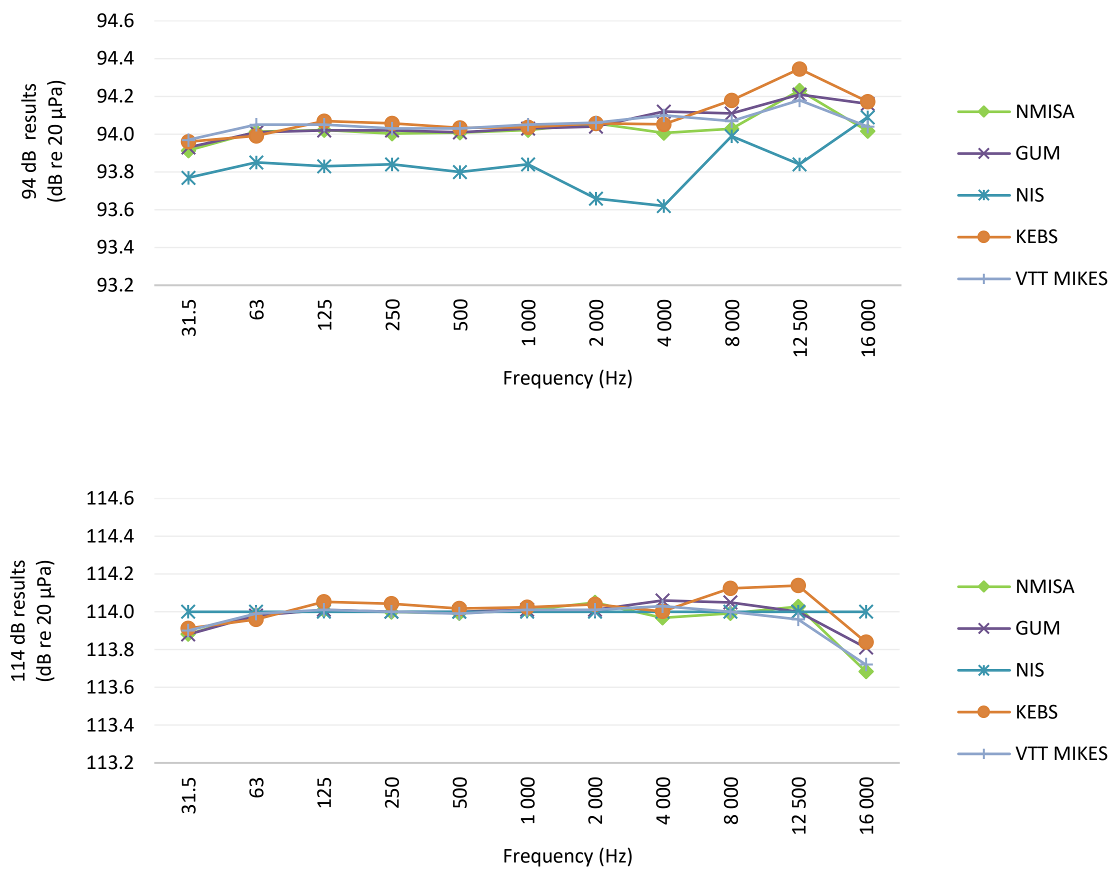


Figure 3. Sound pressure level results from all participants (94 dB top and 114 dB bottom).

7. ANALYSIS OF RESULTS

Sound pressure level results were evaluated by using the Chi-squared (χ^2) method [7] to identify outliers. Weighted Mean (WM), $\bar{x}$, values were calculated at each frequency of the 94 dB and 114 dB sound pressure levels using Equation 1. Uncertainties, $u(\bar{x})$, associated with the weighted mean values were calculated as per Equation 2.

Consistency tests were performed with a 5 % probability that a result might be discrepant, according to Equation 3.

Sound pressure level results and associated uncertainties are logarithmic quantities. Errors introduced in the calculations by not converting these logarithmic quantities to linear and back again to logarithmic quantities are of no meaningful significance.

$$\bar{x} = \frac{\sum_{i=1}^{n}\left({x_i}/{u_i^2}\right)}{\sum_{i=1}^{n}\left({1}/{u_i^2}\right)} \quad (1)$$

$$u(\bar{x}) = \left(\sum_{i=1}^{n}\left({1}/{u_i}\right)^2\right)^{-\frac{1}{2}} \quad (2)$$

$$Pr\{\chi^2(v) > \chi_{obs}^2\} < 0{,}05 \quad (3)$$

where

$\bar{x}$	weighted mean (WM)
x_i	result reported by participant *i*
u_i	uncertainty (*k* = 1) reported by participant *i* for result x_i
n	number of participants
$u(\bar{x})$	uncertainty (*k* = 1) of weighted mean
Pr	probability of
v	degrees of freedom $(n-1)$
χ_{obs}^2	observed χ^2

Outliers were identified, by using the method as described above, for some of the NIS results. Annex C, Tables 16 and 17 indicates the communicated outliers. After consultation with the CCAUV KCWG Chair and careful consideration, the 114 dB sound pressure level results of NIS were excluded from the calculation of the CRV and DoE, as it is unlikely that all sound pressure level results will be exactly equal to the nominal value of 114,00 dB (see Annex B for all participants results).

KEBS requested for other results to be used prior to Draft A and after all participants' measurement results were submitted. None of the originally reported results by KEBS were identified as outliers, thus no other new results were considered, or reported for the calculation of any results in this comparison. This is in line with CIPM MRA-G-11 section 8.1 that only anomalous results identified by the Pilot can be corrected for numerical errors by the respective participant and resubmitted for further evaluation and inclusion in a comparison.

NIS initially submitted all sound pressure level results rounded to one decimal place. The Technical Protocol requirement was that all sound pressure level results should have been reported to two decimal places. NIS was asked to report the results in question to two decimal places, which NIS subsequently submitted. Outliers were subsequently identified and communicated to NIS, upon which no submission of numerically corrected results were received.

NIS requested for new results to be included after the Draft B.1 comparison report were circulated to all participants. No other results of NIS, other than the original decimal anomalous corrected results and identified outliers have been considered in the calculation of reference values for this comparison. This is in line with CIPM MRA-G-11 section 8.1 which ensures the integrity of this AFRIMETS.AUV.A-S2 comparison and therefore its suitability to support CMCs.

8. COMPARISON REFERENCE VALUES

Comparison Reference Values (CRV), x_{CRV}, were calculated for this supplementary comparison and are not linked to another CIPM or RMO KC.

CRVs and the associated expanded uncertainties, $U(x_{CRV})$, were only calculated for the 94 dB and 114 dB sound pressure levels and not for frequency or distortion. CRVs and the associated expanded uncertainties were calculated only from results which passed the consistency tests as the final weighted mean results.

Table 2. Comparison Reference Values and associated uncertainty (k = 2) for 94 dB sound pressure levels

CRVs 94 dB 4226 s/n: 3003604		
Nominal Frequency (Hz)	Sound pressure level (dB re 20 µPa)	$U(x_{CRV})$ (dB)
31,5	93,910	0,039
63	94,003	0,035
125	94,036	0,033
250	94,022	0,033
500	94,017	0,033
1 000	94,030	0,033
2 000	94,054	0,033
4 000	94,054	0,033
8 000	94,066	0,036
12 500	94,230	0,042
16 000	94,072	0,059

Table 3. Comparison Reference Values and
associated uncertainty (k = 2) for 114 dB sound pressure levels

CRVs 114 dB 4226 s/n: 3003604		
Nominal Frequency (Hz)	Sound pressure level (dB re 20 µPa)	$U(x_{CRV})$ (dB)
31,5	113,886	0,042
63	113,983	0,036
125	114,019	0,033
250	114,009	0,033
500	113,999	0,033
1 000	114,013	0,033
2 000	114,033	0,033
4 000	114,004	0,033
8 000	114,017	0,036
12 500	114,022	0,042
16 000	113,734	0,058

9. DEGREES OF EQUIVALENCE

DoE, d_i, were calculated as per Equation 4, and are reported in the Figures 4 to 8 and Tables 4 to 5 below as the coloured markers; the associated uncertainties, $U(d_i)$, are indicated with uncertainty bars. The uncertainties associated with the CRV, $U(x_{CRV})$, are also indicated as the light blue areas. All uncertainties indicated are for a coverage factor of k = 2. It is noted that it is not necessarily a requirement to report DoE for RMO supplementary comparisons [5].

Where an outlier was identified, the associated results were calculated as per Equations 6 and 7.

$$d_i = x_i - x_{CRV} \tag{4}$$

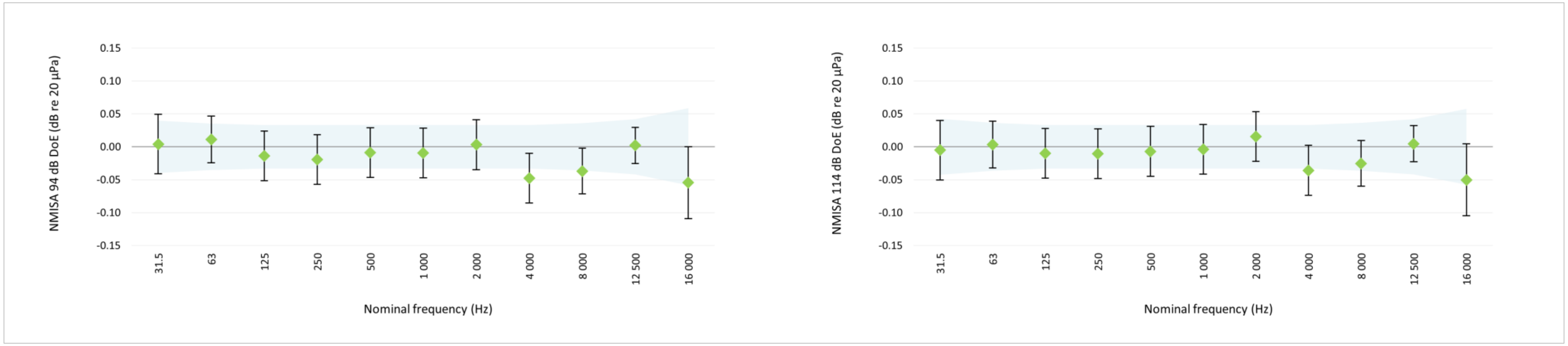
$$u(d_i) = \left(u_i^2 - u(x_{CRV})^2\right)^{\frac{1}{2}} \tag{5}$$

$$d_o = x_o - x_{CRV} \tag{6}$$

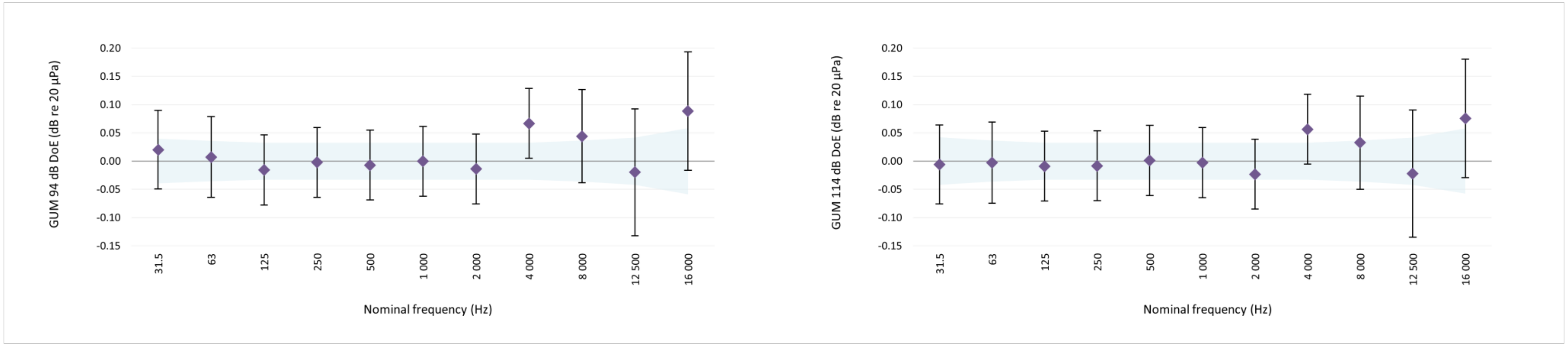
$$u(d_o) = (u_o^2 + u(x_{CRV})^2)^{\frac{1}{2}} \tag{7}$$

where

d_i	DoE value of participant *i*
$u(d_i)$	DoE uncertainty (k = 1) of participant *i*
d_o	identified outlier result
$u(d_o)$	identified outlier uncertainty (k = 1)



Figures 4. NMISA DoE for sound pressure levels 94 dB (left) and 114 dB (right)



Figures 5. GUM DoE for sound pressure levels 94 dB (left) and 114 dB (right)

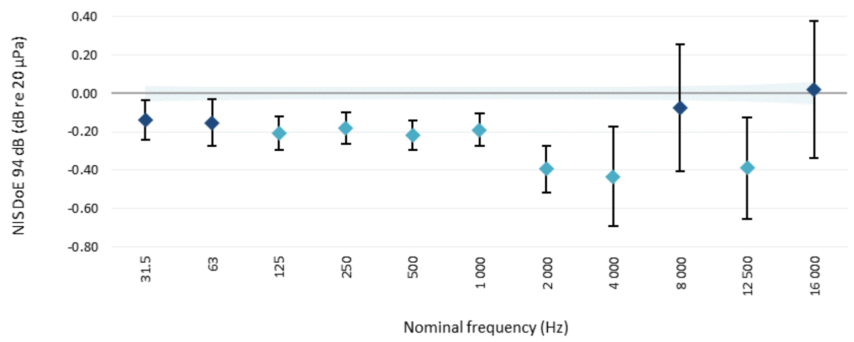
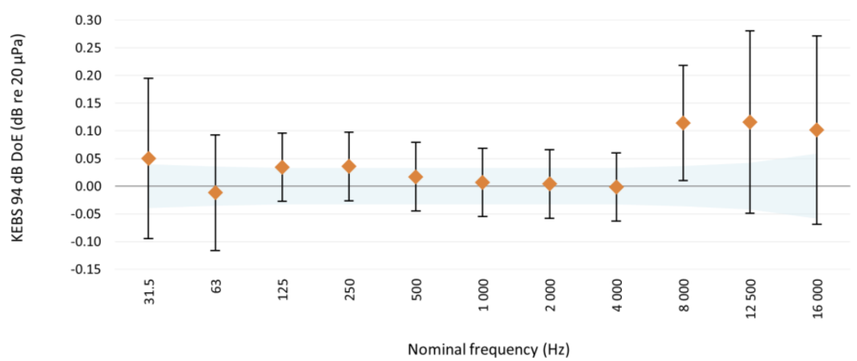
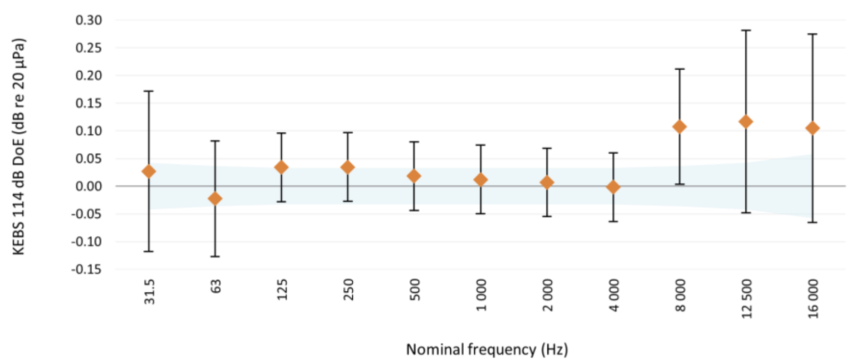
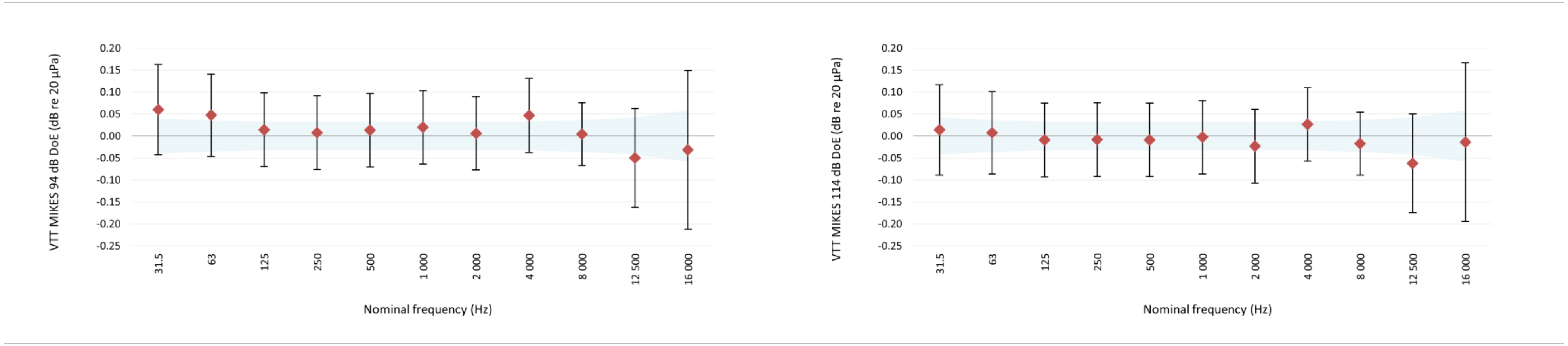


Figure 6. NIS DoE for sound pressure levels 94 dB. Also shown are $\boldsymbol{d_o}$ and $\boldsymbol{U(d_o)}$.
NIS results for 114 dB sound pressure levels were excluded from the calculation of the 114 dB CRVs and DoEs.





Figures 7. KEBS DoE for sound pressure levels 94 dB (left) and 114 dB (right)



Figures 8. VTT MIKES DoE for sound pressure levels 94 dB (left) and 114 dB (right)

Table 4. DoE with associated uncertainties (k = 2) for 94 dB sound pressure levels. *The shaded areas are identified outlier data.

Degrees of Equivalence 94 dB										
Nominal Frequency (Hz)	NMISA		GUM		NIS		KEBS		VTT MIKES	
	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)
31,5	0,004	0,045	0,020	0,070	-0,140	0,104	0,050	0,145	0,060	0,103
63	0,011	0,035	0,007	0,072	-0,153	0,123	-0,012	0,104	0,047	0,094
125	-0,014	0,038	-0,016	0,062	-0,206*	0,087*	0,034	0,062	0,014	0,084
250	-0,019	0,038	-0,002	0,062	-0,182*	0,083*	0,036	0,062	0,008	0,084
500	-0,009	0,038	-0,007	0,062	-0,217*	0,075*	0,017	0,062	0,013	0,084
1 000	-0,009	0,038	0,000	0,062	-0,190*	0,085*	0,007	0,062	0,020	0,084
2 000	0,003	0,038	-0,014	0,062	-0,394*	0,122*	0,004	0,062	0,006	0,084
4 000	-0,048	0,038	0,066	0,062	-0,434*	0,260*	-0,002	0,062	0,046	0,084
8 000	-0,037	0,035	0,044	0,082	-0,076	0,330	0,114	0,104	0,004	0,071
12 500	0,002	0,028	-0,020	0,113	-0,390*	0,262*	0,116	0,165	-0,050	0,113
16 000	-0,055	0,055	0,088	0,105	0,018	0,357	0,101	0,170	-0,032	0,181

Table 5. DoE with associated uncertainties (k = 2) for 114 dB sound pressure levels. NIS results were excluded from the calculation of DoEs.

Degrees of Equivalence 114 dB										
Nominal Frequency (Hz)	NMISA		GUM		NIS		KEBS		VTT MIKES	
	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)	d_i (dB)	$U(d_i)$ (dB)
31,5	-0,005	0,043	-0,006	0,068	-	-	0,027	0,144	0,014	0,102
63	0,003	0,034	-0,003	0,071	-	-	-0,023	0,104	0,007	0,082
125	-0,010	0,038	-0,009	0,062	-	-	0,034	0,062	-0,009	0,084
250	-0,011	0,038	-0,009	0,062	-	-	0,034	0,062	-0,009	0,084
500	-0,007	0,038	0,001	0,062	-	-	0,018	0,062	-0,009	0,084
1 000	-0,004	0,038	-0,003	0,062	-	-	0,012	0,062	-0,003	0,084
2 000	0,016	0,038	-0,023	0,062	-	-	0,007	0,062	-0,023	0,084
4 000	-0,036	0,038	0,056	0,062	-	-	-0,002	0,062	0,026	0,084
8 000	-0,025	0,034	0,033	0,082	-	-	0,108	0,104	-0,017	0,071
12 500	0,005	0,028	-0,022	0,113	-	-	0,117	0,165	-0,062	0,113
16 000	-0,050	0,055	0,076	0,105	-	-	0,105	0,171	-0,014	0,138

10. CONCLUSIONS

The comparison purpose was to address Regional Metrology Organisations (RMOs) NMI members needs for establishing and maintaining measurement equivalence, in accordance with the CIPM MRA. Five NMIs from 2 different RMOs participated in this comparison.

A Brüel & Kjær 4226 s/n: 3003604 multi-frequency sound calibrator was circulated as comparison artefact. Participants reported the sound pressure level, frequency and TD+N results on the 94 dB and 114 dB sound level settings.

Sound pressure level results were evaluated for consistency using the Chi-squared method. Some results were found to be inconsistent with the Comparison Reference Values. Degrees of Equivalence were determined only for 94 dB and 114 dB sound pressure level results.

Results were evaluated, as a secondary aim of the comparison, in accordance with IEC 60942: 2017 Periodic Tests for conformance with acceptance limits and maximum-permitted uncertainties.

This comparison is considered a success as it can serve to support CMCs from the participants.

11. ACKNOWLEDGEMENTS

It is with great appreciation that all the participating NMIs are thanked for contributing their time and other resources in making this comparison possible.

12. REFERENCES

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ANNEX A – PARTICIPANTS METHODS

NOTE
References that appear in the descriptions of a participants' method description and uncertainty matrix do not form part of the main body of text in this report.

NMISA

The sound pressure levels were obtained by using the insert voltage technique, with a Brüel & Kjær 2673 preamplifier and a pressure reciprocity calibrated Brüel & Kjær 4180 LS2aP microphone. The frequency and distortion results were obtained using a Brüel & Kjær 3630 calibration platform with Brüel & Kjær 7794 sound calibrator calibration software.

The Brüel & Kjær 4226 UA-0915 coupler with Brüel & Kjær 4180 microphone and preamplifier were placed inside a pressure chamber that was connected to a buffer tank. The chamber with the buffer tank were pressurised to the nominal reference static pressure of 101,3 kPa. Additionally, the chamber was placed on an optical table with active isolation.

The environmental parameters were measured using a Rotronics Hygroclip probe located inside the pressure chamber and a Vaisala PT330 barometer. The sound pressure level results were corrected to the reference environmental conditions.

The polarizing voltage was 200 Vdc ± 0,05 Vdc.

The results were evaluated for conformance against IEC 60942: 2017 class 1, Annex B.

GUM

The calibration of sound calibrator was performed at the GUM in accordance with IEC 60942: 2017 standard using the microphone method.

The reference microphone used was the LS2P Brüel & Kjær model 4180, calibrated at the GUM using the reciprocity method according to IEC 61094-2: 2009 in September 2019, i.e. about a month before the measurements were taken.

The LS2P microphone coefficients for ambient pressure, temperature and humidity was a polynomial based coefficients at each frequency of interest. The polarisation voltage of 200 V ± 0,05 V was applied to the microphone.

Measurements were performed using B&K PULSE analyser system type 3560. For each signal generated by the calibrator the spectrum (FFT) of the voltage at loaded microphone terminals was averaged over a period of 20 s and recorded. Additionally the voltages U_{loop} and U_{out} required for determination of microphone preamplifier attenuation were measured using the CIC (Charge Injection Calibration) method available in the PULSE system. All measurement results were transferred to the Excel spreadsheet used for calculations of attenuation of the preamplifier, sound pressure level, frequency and total distortion + noise.

The sound pressure level of each signal generated by the calibrator was determined over the frequency range 22,4 Hz – 22,4 kHz and corrected to the reference environmental conditions, using the formulas (1) - (4):

$$L_p = 20\,log\left(\frac{U}{U_{\text{ref}}}\right) + 20\,log\left(\frac{U_{\text{loop}}}{U_{\text{out}}}\right) - L_{S,\text{MC}} + \Delta L_{p,\text{corr}} + 20\,log\left(\frac{1}{20\cdot 10^{-6}}\right),\ \text{dB} \qquad (1)$$

$$U = \left(\sqrt{\frac{\sum_{i=\min}^{\max} U_i^2}{NPBW}}\right) \qquad (2)$$

$$L_{S,\text{MC}} = L_{S,\text{RC}} + c_{m,ps}\cdot\left(p_s - p_{\text{s,ref}}\right) + c_{m,t}\cdot\left(t - t_{\text{ref}}\right) \qquad (3)$$

$$\Delta L_{p,\text{corr}} = c_{c,ps}\cdot\left(p_{\text{s,ref}} - p_s\right) + c_{c,t}\cdot\left(t_{\text{ref}} - t\right) \qquad (4)$$

where:

L_p	–	sound pressure level, at reference conditions, dB
$\Delta L_{p,corr}$	–	correction for the influence of environmental conditions on the sound pressure level of the calibrator, dB
U	–	the voltage at loaded microphone terminals, V
U_{ref}	–	reference voltage of 1 V
U_{loop}/U_{out}	–	microphone preamplifier attenuation, V/V
$L_{S,MC}$	–	microphone sensitivity level at current environmental conditions, dB re 1V/Pa

$L_{S,RC}$	–	microphone sensitivity level at reference conditions, dB re 1V/Pa
$c_{m,ps,}$	–	static pressure coefficient of the microphone, dB/kPa,
p_s	–	static pressure during measurements, kPa,
$p_{s,ref}$	–	reference value of static pressure of 101,325 kPa,
$c_{m,t}$	–	temperature coefficient of the microphone, dB/°C,
t	–	temperature during measurements, °C,
t_{ref}	–	reference temperature of 23 °C,
$c_{c,ps,}$	–	static pressure coefficient of sound calibrator, dB/kPa,
$c_{c,t,}$	–	temperature coefficient of sound calibrator, dB/°C,
U_i	–	voltage at the *i*-th frequency of the FFT spectrum, V; min /max – minimum /maximum frequency of the analysed signal bandwidth,
NPBW	–	Noise Power Bandwidth, compensates for the fact that the FFT window spreads the energy from the signal component at any discrete frequency to adjacent bins, varies depending on the window used.

The frequency of the signal was calculated as the weighted average of the spectral components including the fundamental component and its vicinity (6).

$$f = \frac{\sum_{i=j-3}^{j+3} U_i^2 \cdot i \cdot \Delta f}{\sum_{i=j-3}^{j+3} U_i^2} = \frac{\sum_{i=j-3}^{j+3} U_i^2 \cdot f_i}{\sum_{i=j-3}^{j+3} U_i^2}, \text{ Hz} \qquad (5)$$

where:

U_i	–	voltage at the *i*-th frequency of the FFT spectrum, V
Δf	–	distance between successive bins (FFT resolution), Hz
f_i	–	center frequency of *i*-th bin, Hz
j	–	index relating to the bin of maximum value in the spectrum

The total distortion + noise was calculated as a ratio of the root-mean-square of the total distortion and noise components, to the root-mean-square of the entire signal, measured over the frequency range from 22,4 Hz to 22,4 kHz.

Prior to each series of measurements an ambient noise measurements were taken in accordance with Clause B.4.2 of IEC 60942:2017. The sound pressure level was measured by a microphone after coupling to the sound calibrator, but before switching on and did not exceed 51 dB.

During measurements environmental parameters (temperature, humidity and ambient static pressure) were recorded, they were:

Static pressure:	(98,5 – 100,5) kPa
Ambient temperature:	(22,3 – 23,7) °C
Relative humidity	(34 – 52) %

The measurement uncertainty has been determined in accordance with EA-4/02 M: 2013 document. The reported expanded uncertainty is stated as the standard uncertainty multiplied by the coverage factor $k = 2$, which corresponds to a coverage probability of approximately 95 %.

Sound calibrator comparison method A sound calibrator with a calibrated sound pressure level of the sound generated by the test object sound calibrator Measure in comparison with the sound pressure level of the generated sound or acoustic calibrators that can generate sound at multiple frequencies, the operation manual will Repeat the measurement of the tonal pressure level at the highest and lowest frequencies.

Sound pressure level in the ½ inch coupler of the calibrator was measured with a laboratory grade condenser microphone LS type 4180 (calibrated by DFM and NIS). The measured sound pressure was compared with that generated in the coupler of calibrator whose output was cross checked against calibrator, with the microphone and at the same ambient conditions. Appropriate corrections for atmospheric pressure conditions during calibration and for the measurement frequency and level response were taken into account. Sound pressure level results are the mean of 10measurements.Results apply directly to the following setting on the calibrator , pressure sound field , function calibration , 94 and 114 dB sound level and microphone group a (frequencies 31.5 Hz- 16kHz) Results for frequency and distortion are the results of 10measuresmts.

Connect the microphone to the sound calibrator and in the instruction manual to stabilize the microphone and the sound calibrator. Have time to specify. Then, for the main sound pressure level and the main frequency, the sound calibrator is generated by averaging for 20 seconds

Measure the sound pressure level of the sound you want to For Class LS calibrators, the standard microphones specified in **IEC** 61094-2

> Sound Calibrator Calibration Software for Calibration Platform 3630 is an automated tool to perform periodic tests of calibrators in accordance with the IEC 60942.The software can perform calibration on any single tone, multilevel calibrators at different frequencies. The system uses the comparison method .PULSE Multi-analyzer System can compare the reference sound pressure level with the sound pressure level generated by the tested calibrator and measure frequency and distortion.

Microphone Method The sound pressure level of the sound generated by the test sound calibrator is calibrated using a microphone or is measured using a microphone system. Insertion voltage method (see IEC 61094-2) or open circuit of microphone. An equivalent method of measuring the path voltage may be used

All sound pressure level and frequency combinations described in the instruction manual will comply with this standard. Sound pressure level measurement with the microphone connected (without repetition), repeat. Actual value of each measured value Deviations from the corresponding specified sound pressure level spread out taking into account the expanded uncertainty of the measurement tolerance limits Do not exceed.

The expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k providing a level of confidence of approximately 95%.

The used microphone was calibrated using primary calibration system (reciprocity techniques)

Measurement of pressure sensitivity in accordance with IEC 61094-2:2009 (Reciprocity technique)

The measurements have been performed with the assistance of: Brüel & Kjær Microphone Calibration System

Measurement description for calibration of multifunction acoustic calibrator type 4226 for purposes of the AFRIMETS.AUV.A-S2 comparison.

Measurements were carried out using KEBS procedure MET-15-CP-06 Sound calibrator calibration by insert voltage, in conformance to the requirements of IEC 60942: 2017 and the Technical Protocol AFRIMETS.AUV.V-S2.

The procedure makes use of the following instruments.

- Microphone B&K type 4180 S/No. 2488308
- Insert voltage preamplifier B&K type 2673 S/No. 2416780
- Reciprocity calibration apparatus B&K type 5998 S/No. 2545079
- Band pass filter B&K type 1617 S/No. 2514666
- Reference multi-meter Fluke 8508A S/No. 913152494

The microphone used is a laboratory standard microphone (LS2) calibrated using pressure reciprocity calibration technique fulfilling the requirements of IEC 61094-2:2009 for the modulus of pressure sensitivity level over the frequency range 31.5 Hz to 16 kHz.

Total Distortion was measured using Rohde & Schwarz FSMR Measuring Receiver S/No. 101355.

Calibration was repeated over multiple days and times within the allocated measurement period.

The laboratory conditions, namely temperature, humidity and pressure were monitored continuously during calibration using Fluke Dewk 1620 Thermohygrometer S/No. 465117 and GE Druck Pace 1001 Barometer S/No. 4356695. The average laboratory conditions were

Parameter	Average	Standard deviation
Temperature	23.4 ^{0}C	0.95 ^{0}C
Humidity	49.8 %RH	2.02 %RH
Pressure	840.1 hPa	1.41 hPa

The level was then corrected to standard conditions, namely 23 ^{0}C, 50 % RH and 101, 325 kPa using pressure and temperature coefficients stated in Table 3 of the Technical Protocol.

Description of the method and instrumentation in MIKES

Method

The calibrations were performed according to the so called insert voltage method.

Polynomial based coefficients were used to correct the results to reference ambient conditions.

Most of the measurement hardware and software for performing the measurements and analysing the measurement results are developed in VTT MIKES. Voltages and frequency are measured with two 3458A precision multimeters. TD+noise is measured with HP8903B. During the measurements polarisation voltage was monitored and the value was 200.014 V.

Deviations from the standard

None declared.

Declared parameters

Parameters measured are sound pressure level, frequency and TD+noise.

Calculations

The measurement microphone sensitivity value given in the microphone database represents normal conditions. The measurement program calculates temperature and pressure corrections to be included in the microphone sensitivity value. The equation below shows the sensitivity value in dB for the measurement conditions.

$$M_{dB,Corr} = M_{dB} + \alpha_p(p - p_{ref}) + \alpha_t(t - t_{ref}) + 20\log\left(\frac{U_{pol}}{200\ \mathrm{V}}\right),$$

where

M_{dB} is the microphone sensitivity value in normal conditions,

α_p is the logarithmic barometric pressure dependency coefficient,

p is the barometric pressure,

p_{ref} is the barometric pressure in normal conditions (1013,25 hPa),

α_{t} is the logarithmic temperature dependency coefficient,

t is the ambient temperature (°C),

t_{ref} is the temperature in the normal conditions (23 °C),

U_{pol} is the polarisation voltage during measurements (voltage is kept near 200 volts).

The microphone sensitivity in units V/Pa is calculated from the dB value with expression

$$M_{Corr} = 10^{\frac{M_{dB,Corr}}{20}}.$$

The measurement program calculates the sound pressure level with equation

$$L_{calibrator} = 20 \cdot log_{10}\left(\frac{U}{M_{Corr} G L_{ref}}\right) - c_{p,dB} - c_{V,dB},$$

where

U is the measured insert voltage,

G is the ratio U_1/U_2 where U_1 is measured when the sound source is on and U_2 is measured when the insert voltage is applied.

L_{ref} is the reference sound pressure level 20µPa,

$c_{p,\mathrm{dB}}$ is the pressure correction for the sound calibrator,

$c_{V,\mathrm{dB}}$ is the correction due the additional volume of the microphone.

Pressure and microphone volume corrections are performed only to the pistonphones.

The uncertainty calculation was done according to publication *Evaluation of measurement data – Guide to the expression of uncertainty in measurement (JCGM 100:2008).*

NMISA

Table 6. NMISA reported 94 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	93.914	0.06	31.63	0.01	0.50	0.30
63	94.014	0.05	63.13	0.02	0.17	0.30
125	94.022	0.05	125.88	0.04	0.15	0.30
250	94.003	0.05	251.27	0.08	0.18	0.30
500	94.008	0.05	502.54	0.15	0.33	0.30
1 000	94.021	0.05	1 005.1	0.3	0.40	0.30
2 000	94.057	0.05	1 978.7	0.6	0.45	0.30
4 000	94.006	0.05	3 957.5	1.2	0.68	0.30
8 000	94.029	0.05	7 914.9	2.4	0.40	0.30
12 500	94.232	0.05	12 663.9	3.8	0.32	0.30
16 000	94.017	0.08	15 829.9	4.8	0.30	0.30

Table 7. NMISA reported 114 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	113.881	0.06	31.63	0.01	0.31	0.30
63	113.986	0.05	63.13	0.02	0.13	0.30
125	114.009	0.05	125.88	0.04	0.09	0.30
250	113.998	0.05	251.27	0.08	0.08	0.30
500	113.992	0.05	502.54	0.15	0.15	0.30
1 000	114.009	0.05	1 005.1	0.3	0.24	0.30
2 000	114.049	0.05	1 978.7	0.6	0.31	0.30
4 000	113.968	0.05	3 957.5	1.2	1.31	0.30
8 000	113.992	0.05	7 914.9	2.4	0.25	0.30
12 500	114.027	0.05	12 663.9	3.8	0.09	0.30
16 000	113.684	0.08	15 829.9	4.8	0.11	0.30

GUM

Table 8. GUM reported 94 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	93.93	0.08	31.63	0.05	0.5	0.2
63	94.01	0.08	63.13	0.05	0.2	0.2
125	94.02	0.07	125.9	0.1	0.3	0.2
250	94.02	0.07	251.3	0.1	0.4	0.2
500	94.01	0.07	502.5	0.1	0.5	0.2
1 000	94.03	0.07	1 005.1	0.1	0.5	0.2
2 000	94.04	0.07	1 978.7	0.1	0.6	0.2
4 000	94.12	0.07	3 957.5	0.1	0.7	0.2
8 000	94.11	0.09	7 914.9	0.1	0.5	0.2
12 500	94.21	0.12	12 663.9	0.1	0.4	0.2
16 000	94.16	0.12	15 829.9	0.2	0.4	0.2

Table 9. GUM reported 114 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	113.88	0.08	31.63	0.05	0.2	0.2
63	113.98	0.08	63.13	0.05	0.2	0.2
125	114.01	0.07	125.9	0.1	0.2	0.2
250	114.00	0.07	251.3	0.1	0.1	0.2
500	114.00	0.07	502.5	0.1	0.2	0.2
1 000	114.01	0.07	1 005.1	0.1	0.2	0.2
2 000	114.01	0.07	1 978.7	0.1	0.3	0.2
4 000	114.06	0.07	3 957.5	0.1	1.3	0.2
8 000	114.05	0.09	7 914.9	0.1	0.3	0.2
12 500	114.00	0.12	12 663.9	0.1	0.1	0.2
16 000	113.81	0.12	15 829.9	0.2	0.2	0.2

NIS

Table 10. NIS reported 94 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	93.77	0.111	31.63	0.008	0.44	0.056
63	93.85	0.128	63.13	0.008	0.03	0.06
125	93.83	0.081	125.88	0.028	0.05	0.056
250	93.84	0.076	251.32	0.028	0.07	0.061
500	93.80	0.068	502.46	0.045	0.07	0.056
1 000	93.84	0.078	1005	0.298	0.18	0.056
2 000	93.66	0.117	1983.8	0.267	0.30	0.090
4 000	93.62	0.258	3960.3	0.427	0.55	0.075
8 000	93.99	0.332	7922.3	0.427	0.20	0.063
12 500	93.84	0.259	12660.2	0.4	0.07	0.056
16 000	94.09	0.362	15842	2.667	0.10	0.057

Table 11. NIS reported 114 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	114.00	0.181	31.63	0.008	0.29	0.056
63	114.00	0.193	63.13	0.008	0.13	0.056
125	114.00	0.164	125.89	0.013	0.08	0.055
250	114.00	0.164	251.3	0.017	0.07	0.055
500	114.00	0.164	502.49	0.013	0.05	0.055
1 000	114.00	0.165	1004.9	0.100	0.19	0.055
2 000	114.00	0.177	1983.8	0.134	0.30	0.056
4 000	114.00	0.292	3959.9	0.100	1.27	0.060
8 000	114.00	0.338	7921.9	0.100	0.18	0.056
12 500	114.00	0.201	12657.5	0.670	0.05	0.055
16 000	114.00	0.349	15840.5	0.500	0.14	0.058

KEBS

Table 12. KEBS reported 94 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result (dB)	UoM (dB)	Result (Hz)	UoM (%)	Result (%)	UoM (%)
31.5	93.96	0.15	31.6	0.2	1.5	0.5
63	93.99	0.11	63.1	0.2	0.7	0.5
125	94.07	0.07	125.9	0.2	0.6	0.5
250	94.06	0.07	251.3	0.2	1.6	0.5
500	94.03	0.07	502.5	0.2	0.9	0.5
1 000	94.04	0.07	1005.1	0.2	0.5	0.5
2 000	94.06	0.07	1978.7	0.2	0.5	0.5
4 000	94.05	0.07	3957.5	0.2	1.0	0.5
8 000	94.18	0.11	7914.9	0.2	0.4	0.5
12 500	94.35	0.17	12663.9	0.2	0.6	0.5
16 000	94.17	0.18	15829.8	0.2	0.5	0.5

Table 13. KEBS reported 114 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result (dB)	UoM (dB)	Result (Hz)	UoM (%)	Result (%)	UoM (%)
31.5	113.91	0.15	31.6	0.2	0.3	0.5
63	113.96	0.11	63.1	0.2	0.1	0.5
125	114.05	0.07	125.9	0.2	0.1	0.5
250	114.04	0.07	251.3	0.2	0.1	0.5
500	114.02	0.07	502.5	0.2	0.1	0.5
1 000	114.03	0.07	1005.1	0.2	0.1	0.5
2 000	114.04	0.07	1978.7	0.2	0.1	0.5
4 000	114.00	0.07	3957.5	0.2	1.4	0.5
8 000	114.13	0.11	7914.9	0.2	0.1	0.5
12 500	114.14	0.17	12663.9	0.2	0.1	0.5
16 000	113.84	0.18	15829.8	0.2	0.1	0.5

Table 14. VTT MIKES reported 94 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	93.97	0.11	31.6	0.1	0.9	0.3
63	94.05	0.10	63.1	0.1	0.6	0.3
125	94.05	0.09	125.9	0.1	0.6	0.3
250	94.03	0.09	251.3	0.1	0.6	0.3
500	94.03	0.09	502.5	0.1	0.7	0.3
1 000	94.05	0.09	1 005.1	0.1	0.7	0.3
2 000	94.06	0.09	1 978.7	0.2	0.8	0.3
4 000	94.10	0.09	3 957.5	0.4	0.9	0.3
8 000	94.07	0.08	7 914.9	0.8	0.7	0.3
12 500	94.18	0.12	12 663.9	1.2	0.5	0.4
16 000	94.04	0.19	15 829.8	1.5	0.6	0.4

Table 15. VTT MIKES reported 114 dB results

Frequency setting (Hz)	Lp (dB re 20 µPa)		Frequency (Hz)		TD+N (%)	
	Result	UoM	Result	UoM	Result	UoM
31.5	113.90	0.11	31.6	0.1	0.3	0.3
63	113.99	0.09	63.1	0.1	0.1	0.3
125	114.01	0.09	125.9	0.1	0.1	0.3
250	114.00	0.09	251.3	0.1	0.1	0.3
500	113.99	0.09	502.5	0.1	0.1	0.3
1 000	114.01	0.09	1 005.1	0.1	0.2	0.3
2 000	114.01	0.09	1 978.7	0.2	0.3	0.3
4 000	114.03	0.09	3 957.5	0.4	1.4	0.3
8 000	114.00	0.08	7 914.9	0.8	0.2	0.3
12 500	113.96	0.12	12 663.9	1.2	0.1	0.4
16 000	113.72	0.15	15 829.8	1.5	0.1	0.4

ANNEX C – PARTICIPANTS’ UNCERTAINTY OF MEASUREMENT MATRIXES

NMISA

	AVIAS-4748		94 dB & 114 dB Sound pressure level Frequency (Hz)										
	B&K 4226 s/n: 3003604		31.5	63	125	250	500	1 000	2 000	4 000	8 000	12 500	16 000
Symbol	Standards/Ref Equipment	Qty	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$	$u_i(y)$
M_P	Reference microphone	-38 dB	0.0250	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0200	0.0200	0.0300
V_P	Polarization voltage accuracy	(200 ± 0,25) V	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
A_{V1}	USB Daq DC accuraccy, Channel 0	± 10 V	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075
A_{V2}	USB Daq DC accuraccy, Channel 1	± 10 V	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075
$V_{0,SAM}$	Voltage signal accuracy	± 10 V	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
$V_{1,SAM}$	Voltage signal accuracy	± 10 V	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
G_F	Generator frequency accuracy		0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
$C_{P,Ref}$	Microphone pressure correction	(1013 ± 5) mbar	0.0058	0.0058	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
$C_{t,Ref}$	Microphone temperature correction	(23 ± 1) °C	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
$C_{H,Ref}$	Microphone humidity correction	50% RH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D_{Mp}	Reference microphone sensitivity drift	-38 dB	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
	UUT												
$C_{P,UUT}$	Source pressure correction	(1013 ± 5) mbar	0.0058	0.0058	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
$C_{t,UUT}$	Source temperature correction	(23 ± 1) °C	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
$C_{h,UUT}$	Source humidity correction	50% RH	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Repeatibility ESDM	dB	0.012	0.014	0.007	0.011	0.007	0.006	0.005	0.004	0.003	0.002	0.018
Without external generator	94 dB & 114 dB												
	$L_p\ U_{(k=2)}$	**dB**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.08**

Uncertainty budget of sound pressure level measurement of B&K 4226 multi-frequency calibrator with LS2P microphone

Uncertainty component	Standard uncertainty (in dB) at a frequency, in Hz:										
	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Open-circuit voltage of microphone	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0200
Pressure sensitivity level of microphone	0,0250	0,0250	0,0200	0,0200	0,0150	0,0150	0,0150	0,0150	0,0250	0,0400	0,0400
Change of microphone sensitivity due to drift	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173	0,0173
Influence of polarization voltage	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029
Influence of static pressure on microphone	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007	0,0007
Influence of temperature on microphone	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004
Influence of static pressure on calibrator	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137	0,0137
Influence of temperature on calibrator	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012
Rounding	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029
Repeatability	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0150	0,0200	0,0300	0,0300
Combined uncertainty	**0,0365**	**0,0365**	**0,0333**	**0,0333**	**0,0305**	**0,0305**	**0,0305**	**0,0325**	**0,0404**	**0,0557**	**0,0584**
Expanded uncertainty (*k*=2)	**0,0730**	**0,0730**	**0,0666**	**0,0666**	**0,0611**	**0,0611**	**0,0611**	**0,0650**	**0,0808**	**0,1115**	**0,1167**
CMC	**0,08**	**0,08**	**0,07**	**0,07**	**0,07**	**0,07**	**0,07**	**0,07**	**0,09**	**0,12**	**0,12**

Source of uncertainty
A-Reference microphone

Calibration of reference microphone used (Type A , Normal distribution)
The microphone coupled to calibrator is of IEC type LS2, the reported uncertainties lies in the range of 0.015-0.025dB

Drift in sensitivity level between two successive calibrations (Type B, Normal distribution)
The sensitivity levels of the microphones will be seen to drift by a small amount between calibrations, Uncertainties for an interval between calibrations of the reference standard of two times, it lies in the range of 0.0087 – 0.10dB

Difference in sensitivity level between calibration frequencies(Type B, Rectangular distribution)
The sensitivity level of the reference microphone may differ between the frequency at which it is calibrated and the frequency of the calibrator under test. The difference in uncertainty of pressure sensitivity between the frequencies of interest , it lies in the range 0.00080 – 0.115dB

Influence of environmental conditions (static pressure, air temperature, relative humidity)(Type B, Rectangular distribution)

The influence of any deviation from reference environmental conditions on the sound pressure level is well established for most models. It lies in the order of magnitude of (a- pressure {0.0016}) , (b-temperature { 4.61013E-06 - 0.0030}) and (c-humidity-{0.00062 – 0.00065}) for any error in the applied correction, and estimation of uncertainty .

Polarizing voltage(Type B, Rectangular distribution)

Where the polarizing voltage applied to the microphone strays from the nominal value, an error in the sensitivity level of the microphone is introduced. The uncertainty is 0.00017dB.

B-calibrator under test

The characteristics of calibrator is known:

Effective load volume of microphone(Type B, Rectangular distribution)

The sound pressure level of the calibrator is measured at the diaphragm of a microphone that is coupled to the calibrator. Therefore, the measured sound pressure level is dependent on the geometry of the microphone and the susceptibility of the calibrator to changes in the effective load volume of the microphone. For convenience, the influence of these effects is discussed in this section. The difference in the level of a CALIBRATOR coupled to microphones of different effective load volumes is well known.

a correction for the difference between the actual effective load volume of the microphone and the nominal value for the CALIBRATOR.

Influence of environmental conditions (static pressure, air temperature, relative humidity)(Type B, Rectangular distribution)

Modern models of electronic sound calibrator generally have very small sensitivities to changes in static pressure, while some models may show widely varying changes in sound pressure level.

Performing the calibration in rooms that provide control temperature to within ± 1 °C of the reference temperature of 23 °C,Relative humidity may also be controlled.

Measurement method

1-Sound pressure level

Repeatability of SPL(Type A, Normal distribution)

laboratory perform ten replications of the measurements in order to establish the repeatability of the test, calculate a Type A uncertainty contribution, based on either the actual results of the repeatability.

Resolution of reported SPL (Type B, Rectangular distribution)

Reporting the sound pressure level to two decimal places of decibels and therefore include an uncertainty term of magnitude.

Error in the voltage (Type B, Rectangular distribution)

uncertainty in calibration of the voltmeter

2-Frequency

Repeatability of frequency (Type A, Normal distribution)

laboratory perform ten replications of the measurements in order to establish the repeatability of the test, calculate a Type A uncertainty contribution, based on either the actual results of the repeatability.

Calibration of DMM(calibration certificate)(Type A, Normal distribution)

TheDMM used is previously calibrated with its certificate and uncertainty value

Rounding error (Type B, Rectangular distribution)

The result is reported with a resolution of 0.01 Hz, giving a semi -range of 0.002Hz with a rectangular distribution

Accuracy of the meter to measure frequency (Type B, Rectangular distribution)

adding or subtracting the error value in the calibration certificate of generator at each frequency

3-Total harmonic distortion THD

Repeatability of THD (Type A, Normal distribution)

laboratory perform ten replications of the measurements in order to establish the repeatability of the test, calculate a Type A uncertainty contribution, based on either the actual results of the repeatability.

Resolution (Type B, Rectangular distribution)

How small of change can be read 0.01% with the used device

Accuracy of pulse (Type A, Normal distribution)

Thepulse generator used is previously calibrated with its certificate and uncertainty values

Rounding error (Type B, Rectangular distribution)

The result is reported with a resolution of 0.01 %, giving a semi -range of 0.002% with a rectangular distribution

Instability for distortion readings (Type B, Rectangular distribution)

Fluctuation that may be occurred in the reading values during the measurements

Microphone Distortion (Type B, Rectangular distribution)

The standard microphone B&K 4180 used has distortion value that can affect the THD% value during the calibration. So, it must be taken in consideration.

Pre-amplifier Distortion (Type B, Rectangular distribution)

The pre-amplifier has a distortion value that must be taken in consideration

Sound pressure level measurements - B&K 4226 at 94 dB

freque	freque	freque	freque	freque	freque	freque	freque	freque	freque	frequency(Hz)	unit	distrib	Type	Source of uncertainity
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5				
														Reference microphone
0.025	0.02	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.04	dB	Normal	A	Calibration of refernce microphone used
0.1	0.054	0.032	0.016	0.009	0.009	0.009	0.009	0.01	0.05	0.012	dB	Normal	B	drift in sensitivity level between two sucessive
0.116	0.019	0.145	0.12	0.033	0.008	9E-04	0.002	0.003	0.003	0.004	dB	Rectang	B	difference in sensitivity level between calibrati
0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	dB	Rectang	B	influence of static pressure (by Manufacture)
3E-04	3E-04	3E-04	2E-04	2E-04	2E-04	1E-04	8E-05	4E-05	5E-06	3E-05	dB	Rectang	B	influence of air temperature (by Manufacture)
7E-04	7E-04	7E-04	7E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	dB	Rectang	B	influence of relative humidity (by Manufactur
2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectang	B	polarizing voltage (by Manufacture)
0.155	0.061	0.149	0.122	0.037	0.019	0.017	0.018	0.018	0.054	0.042			K=2	Combined uncertainity
														calibrator under test
2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectang	B	influence of static pressure (from Inter-compa
6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	dB	Rectang	B	influence of air temperature (from Inter-comp
0	0	0	0	0	0	0	0	0	0	0	dB	Rectang	B	influence of relative humidity (from Inter-cor
2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectangular		Effective volume of sound calibrator
6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04			K=2	Combined uncertainity
														Measurement method
0.089	0.111	0.067	0.029	0.034	0.016	5E-15	0.016	0.021	0.017	0.021	dB	Normal	A	repetability of SPL measurements
0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	dB	Rectang	B	Resolution of reputed SPL
0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	dB	Rectang	B	Error in the voltage
0.093	0.115	0.073	0.041	0.045	0.033	0.029	0.033	0.036	0.034	0.036				Combined uncertainity
0.181	0.13	0.166	0.129	0.058	0.039	0.034	0.038	0.04	0.064	0.055				Combined uncertainity
0.362	0.259	0.332	0.258	0.117	0.077	0.068	0.076	0.081	0.127	0.111				expanded uncertainity Uexp.(@K=2)

Frequency(Hz)- B&K 4226

frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequency(Hz)				
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5				
											unit			Measurements
1.333	0.2	0.213	0.213	0.133	0.149	0.022	0.013	0.013	2E-15	1E-15	Hz	Normal	A	repetability
3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	Hz	Normal	A	calibration of DMM(calibration certificate)
0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Hz	Rectan	B	rounding error
0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Hz	Rectan	B	resoltion of DMM
9E-04	7E-04	4E-04	2E-04	1E-04	5E-05	2E-05	5E-06	4E-06	2E-05	2E-05	Hz	Rectan	B	accuracy of the meter to measure frequency
1.333	0.2	0.213	0.213	0.133	0.149	0.022	0.014	0.014	0.004	0.004				Combined uncertainity
2.667	0.4	0.427	0.427	0.267	0.298	0.045	0.028	0.028	0.008	0.008				expanded uncertainity Uexp.(@K=2)

THD total harmonic distortion

frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequer	frequency(Hz)				
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5				
											unit			measurements
0.008	0.004	0.016	0.024	0.035	0.002	0.003	0.014	0.006	0.002	0.004	%	Normal	A	repetability
0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectan	B	resolution
0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	%	Normal	A	Accuracy of pulse
0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectan	B	rounding error
0.003	0.003	0.003	0.007	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectan	B	Instability for distortion readings
9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	%	Rectan	B	Microphone Distortion
3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	%	Rectan	B	Pre-amplifier Distortion
0.029	0.028	0.032	0.037	0.045	0.028	0.028	0.031	0.028	0.028	0.028				Combined uncertainity
0.057	0.056	0.063	0.075	0.09	0.055	0.055	0.061	0.056	0.055	0.055				expanded uncertainity Uexp.(@K=2)

Sound pressure level measurements - B&K 4226 at 114dB

Uncertianty Budget of Sound pressure level measurements - B&K 4226 at 114dB

frequency(I	frequency(Hz	frequency(Hz)	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(I	frequency(Hz)	unit	distribution Type	Source of uncertainty
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5	16000	12500	8000	4000	2000	1000	500	250	125	63	31.5			
																								Reference microphone
0.025	0.02	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.04	0.025	0.02	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.04	dB	Norma A	Calibration of refernce microphone used
0.1	0.054	0.0323	0.016	0.009	0.009	0.009	0.009	0.01	0.05	0.012	0.1	0.054	0.032	0.016	0.009	0.009	0.009	0.009	0.01	0.05	0.012	dB	Norma B	drift in sensitivity level between two sucessive calibrations
0.116	0.0188	0.1445	0.12	0.033	0.008	9E-04	0.002	0.003	0.003	0.004	0.116	0.019	0.145	0.12	0.033	0.008	9E-04	0.002	0.003	0.003	0.004	dB	Rectan B	difference in sensitivity level between calibration frequencies
0.002	0.0016	0.0016	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	dB	Rectan B	influence of static pressure (by Manufacture)
3E-04	0.0003	0.0003	2E-04	2E-04	2E-04	1E-04	8E-05	4E-05	5E-06	3E-05	3E-04	3E-04	3E-04	2E-04	2E-04	2E-04	1E-04	8E-05	4E-05	5E-06	3E-05	dB	Rectan B	influence of air temperature (by Manufacture)
7E-04	0.0007	0.0007	7E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	7E-04	7E-04	7E-04	7E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	dB	Rectan B	influence of relative humidity (by Manufacture)
2E-04	0.0002	0.0002	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectan B	polarizing voltage (by Manufacture)
0.155	0.0606	0.1488	0.122	0.037	0.019	0.017	0.018	0.018	0.054	0.042	0.155	0.061	0.149	0.122	0.037	0.019	0.017	0.018	0.018	0.054	0.042		K=2	Combined uncertainity
																								calibrator under test
2E-04	0.0002	0.0002	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectan B	influence of static pressure (from Inter-comparison protocol)
6E-04	0.0006	0.0006	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	dB	Rectan B	influence of air temperature (from Inter-comparison protocol)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	dB	Rectan B	influence of relative humidity (from Inter-comparison protocol)
2E-04	0.0002	0.0002	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	dB	Rectangular	Effective volume of sound calibrator
6E-04	0.0006	0.0006	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04	6E-04		K=2	Combined uncertainity
																								Measurement method
0.075	0.0745	0.0745	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	dB	Norma A	repetability of SPL measurements
0.029	0.0289	0.0289	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	dB	Rectan B	Resolution of reputed SPL
0.004	0.0041	0.0041	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	dB	Rectan B	Error in the voltage
0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08			Combined uncertainity
0.174	0.1004	0.169	0.146	0.088	0.082	0.082	0.082	0.082	0.097	0.09	0.174	0.1	0.169	0.146	0.088	0.082	0.082	0.082	0.082	0.097	0.09			Combined uncertainity
0.349	0.2008	0.338	0.292	0.177	0.165	0.164	0.164	0.164	0.193	0.181	0.349	0.201	0.338	0.292	0.177	0.165	0.164	0.164	0.164	0.193	0.181			expanded uncertainity Uexp.(@K=2)

Frequency(Hz)- B&K 4226 | uncertanty Budget of Frequency(Hz)- B&K 4226

frequen	frequenc	frequenc	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequency(Hz)				
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5	16000	12500	8000	4000	2000	1000	500	250	125	63	31.5				
																						unit			Measurements
0.25	0.3345	0.05	0.05	0.067	0.05	0.005	0.007	0.005	1E-15	6E-16	0.25	0.335	0.05	0.05	0.067	0.05	0.005	0.007	0.005	1E-15	6E-16	Hz	Normal	A	repetability
3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	Hz	Normal	A	calibration of DMM(calibration certificate)
0.003	0.0029	0.0029	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Hz	Rectang	B	rounding error
0.003	0.0029	0.0029	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	Hz	Rectang	B	resoltion of DMM
9E-04	0.0007	0.0004	2E-04	1E-04	5E-05	2E-05	5E-06	4E-06	2E-05	2E-05	9E-04	7E-04	4E-04	2E-04	1E-04	5E-05	2E-05	5E-06	4E-06	2E-05	2E-05	Hz	Rectang	B	accuracy of the meter to measure frequency
0.25	0.3346	0.0502	0.05	0.067	0.05	0.006	0.008	0.006	0.004	0.004	0.25	0.335	0.05	0.05	0.067	0.05	0.006	0.008	0.006	0.004	0.004				Combined uncertainity
0.5	0.6691	0.1003	0.1	0.134	0.1	0.013	0.017	0.013	0.008	0.008	0.5	0.669	0.1	0.1	0.134	0.1	0.013	0.017	0.013	0.008	0.008				expanded uncertainity Uexp.(@K=2)

THD total harmonic distortion | THD total harmonic distortion

frequen	frequenc	frequenc	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequen	frequency(Hz)				
16000	12500	8000	4000	2000	1000	500	250	125	63	31.5	16000	12500	8000	4000	2000	1000	500	250	125	63	31.5				
																						unit			measurements
0.009	0.0008	0.0034	0.009	0.005	0.001	8E-04	8E-04	0.001	0.003	0.004	0.009	8E-04	0.003	0.009	0.005	0.001	8E-04	8E-04	0.001	0.003	0.004	%	Normal	A	repetability
0.003	0.0029	0.0029	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectang	B	resolution
0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	%	Normal	A	Accuracy of pulse
0.003	0.0029	0.0029	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectang	B	rounding error
0.003	0.0029	0.0029	0.007	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.007	0.003	0.003	0.003	0.003	0.003	0.003	0.003	%	Rectang	B	Instability for distortion readings
9E-04	0.0009	0.0009	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	9E-04	%	Rectang	B	Microphone Distortion
3E-04	0.0003	0.0003	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	3E-04	%	Rectang	B	Pre-amplifier Distortion
0.029	0.0275	0.0277	0.03	0.028	0.027	0.027	0.027	0.027	0.028	0.028	0.029	0.027	0.028	0.03	0.028	0.027	0.027	0.027	0.027	0.028	0.028				Combined uncertainity
0.058	0.0549	0.0553	0.06	0.056	0.055	0.055	0.055	0.055	0.055	0.055	0.058	0.055	0.055	0.06	0.056	0.055	0.055	0.055	0.055	0.055	0.055				expanded uncertainity Uexp.(@K=2)

KEBS Acoustics and Vibration Laboratory
IV-Sound Calibrator Calibration Unc.xlsx

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Uncertainty Budget for sound calibrator level measurement using Reference microphone B&K 4180, Reciprocity calibration system B&K Type 5998 and Fluke 8508A Reference Multi-Meter.

The measurement model $L_p = \frac{V_{o(Meas)}}{S_{o(Meas)}} + TempCorr + PressCorr$

Where L_p is the sound output level of the sound calibrator under test.
$V_{o(Meas)}$ is the open circuit voltage output of the reference microphone at measurment conditions
$S_{o(Meas)}$ is the open circuit sensitivity of the reference microphone at measurement conditions
TempCorr is the temperature correction to standard conditions
PressCorr is the pressure correction to standard conditions

Contributors	Type	Distribution	Uncertainty Source/description	Uncertainty $u(x_i)$	Divisor	Standard Uncertainty $u(y_i)$											Unit
						31.6 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	12.5 kHz	16 kHz	
Microphone calibration uncertainty	B	N	Microphone calibration uncertainty	0.07 dB at 31.6 kHz, 0.04 dB between 31.6 kHz to 8 kHz, and 0.07 dB above 8 kHz	2.00	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04	dB
Deviation from sensitivity at measurement conditions	B	R	Maximum deviation from reported measurement conditions for which microphone sensitivity at measurement conditions is valid	0.02 dB below 8 kHz and 0.04 dB above 8 kHz	2√3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	dB
Low frequency pressure leakage	B	R	Estimate based on expected output	0.03 dB at 31.6 Hz and 0.005 above 31.6 Hz and below 8 kHz, and 0.00 above 8 kHz	2√3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Microphone sensitity deviation at specific 4226 frequency	B	R	Microphone sensitivity response curve	Negligible upto 1 kHz, 0.00042 dB at 2 kHz, 0.0012 dB at 4 kHz, 0.0015 dB at 8 kHz, 0.0057 dB at 12.5 kHz, and 0.001 at 16 kHz.	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Reference multimeter calibration	B	N	Reference multimeter calibration certificate	0.041 dB ≤ 63 Hz, 0.033 dB from 125 Hz to 4 kHz, 0.04 dB at 8 kHz, 0.055 dB ≥ 12.5 kHz	2.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	dB
Signal noise and distortion	B	R	From laboratory checks	≤ 0.002 dB	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Polarisation voltage	B	R	From laboratory measurement	Estimated to be less than 0.001 dB for polarization voltage within ± 0.01 V of 200 V.	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Insert voltage measurement uncertainty	B	R	From reference documentation		2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Resolution	B	R	Reference multimeter effective resolution	0.0003 dB	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Type 5998 gain	B	R	From laboratory measurements	0.2 dB at 31.6 Hz, 0.14 dB at 63 Hz, ≤ 0.05 dB above 63 Hz	2√3	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	dB
Temperature stabiltiy during measurement	B	R	Difference between maximum and minimum temperature during measurements	< 1 °C translating to less than 0.002 dB	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Frequency dependence of temperature correction coefficient	B	R	Deviation of temperature coefficient from value at 250 Hz	≤ 0.0004 dB upto 4 kHz, < 0.003 dB at 8 kHz, ≤ 0.006 dB from 12.5 kHz to 16 kHz	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Pressure stability during measurement	B	R	Difference between maximum and minimum pressure during measurements	< 2 hPa translating to less than 0.00055 dB	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	dB
Frequency dependence of pressure correction coefficient	B	R	Deviation of pressure coefficient from value at 250 Hz	≤ 0.006 dB from 31.6 Hz to 2 kHz, 0.004 dB at 4 kHz, 0.13 dB at 8 kHz and 0.23 dB from 12.5 kHz to 16 kHz	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.07	dB
Repeatability	A	N	Standard deviation of replicated measurements	0.01 dB below 2 kHz, 0.02 dB at 4 kHz, 0.04 dB at 8 kHz to 12.5 kHz, 0.07 dB at 16 kHz	√(N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	dB
Combined Standard Uncertainty $u_c(y)$						0.07	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.08	0.09	dB
Coverage Factor for 95.45%						2	2	2	2	2	2	2	2	2	2	2	
Expanded Uncertainty **U**						**0.15**	**0.11**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.11**	**0.17**	**0.18**	dB
Stated Values						**0.15**	**0.11**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.11**	**0.17**	**0.18**	dB
						31.6 Hz	**63 Hz**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**	**8 kHz**	**12.5 kHz**	**16 kHz**	

$u_c(y)$ is the combined standard uncertainty and is given by $\sqrt{u(y_1)^2+u(y_2)^2...+u(y_n)^2}$

The expanded uncertainty **U** is then given by multiplying the standard uncertainty $u_c(y)$ by a coverage factor of **2**. The unit of uncertainty is dB.

Uncertainty Budget for sound calibrator frequency measurement using Reference microphone B&K 4180, Reciprocity calibration system B&K Type 5998 and Fluke 8508A Reference multimeter.

Contributors	Type	Distribution	Uncertainty Source/description	Uncertainty $u(x_i)$	Divisor	Standard Uncertainty $u(y_i)$											Unit
						31.6 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	12.5 kHz	16 kHz	
Reference multimeter	B	N	Multimeter frequency calibration certificate	0.16 % maximum across all frequencies	2.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	%
Calibration chain	B	R	Maximum distortion of the signal due to pre-amplifier, reciprocity aparatus and band pass filter	0.0025 % at 31.6 Hz, 0.0013 % at 63 Hz, ≤ 0.0007 % above 63 Hz.	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	%
Repeatability	A	N	Standard deviation of replicated measurements	0.001% at 31.6 Hz, ≤ 0.0002% above 31.6 Hz	√(N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	%
Combined Standard Uncertainty **$u_c(y)$**						0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	%
Coverage Factor for 95.45%						2	2	2	2	2	2	2	2	2	2	2	
Expanded Uncertainty **U**						**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	**0.17**	%
Stated Values						**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	%

$u_c(y)$ is the combined standard uncertainty and is given by $\sqrt{u(y_1)^2 + u(y_2)^2 ... + u(y_n)^2}$ The expanded uncertainty **U** is then given by multiplying the standard uncertainty **$u_c(y)$** by a coverage factor of **2**. The unit of uncertainty is percent, relative to the frequency measurement.

Uncertainty Budget for sound calibrator distortion measurement using Reference microphone B&K 4180, Reciprocity calibration system B&K Type 5998 and Rohde & Schwarz R&S FSMR Measuring Receiver.

Contributors	Type	Distribution	Uncertainty Source/description	Uncertainty u(xi)	Divisor	Standard Uncertainty $u(y_i)$											Unit
						31.6 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	12.5 kHz	16 kHz	
FSMR Receiver Residual noise	B	R	Manufucturer specification	0.007 %	2√3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	%
FSMR Receiver Inherent total harmonic distortion	B	R	Manufucturer specification	<0.2% above 100 Hz, estimated to be <0.5% below 100 Hz	2√3	0.14	0.14	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	%
Microphone system	B	R	Maximum levels based on laboratory checks	0.03 % at 31.6 Hz, 0.02 % at 63 Hz, 0.01 % from 125 Hz to 12.5 kHz, and 0.02 % at 16 kHz	2√3	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	
Repeatability	A	N	Standard deviation of replicated measurements	≤ 0.2 % across all frequencies	√(N)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	%
Combined Standard Uncertainty **$u_c(y)$**						0.20	0.20	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	%
Coverage Factor for 95.45%						2	2	2	2	2	2	2	2	2	2	2	
Expanded Uncertainty **U**						**0.41**	**0.41**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	**0.31**	%
Stated Values						**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	%

$u_c(y)$ is the combined standard uncertainty and is given by $\sqrt{u(y_1)^2 + u(y_2)^2 ... + u(y_n)^2}$ The expanded uncertainty **U** is then given by multiplying the standard uncertainty **$u_c(y)$** by a coverage factor of **2**. The unit of uncertainty is percent, relative to the frequency measurement.

Uncertainty budget for level at 94 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Microphone sensitivity	0,0400	0,0300	0,0250	0,0250	0,0250	0,0250	0,0250	0,0250	0,0250	0,0400	0,0500
Barometric pressure	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0002	0,0003	0,0006
Pressure dependency	0,0343	0,0342	0,0349	0,0346	0,0345	0,0335	0,0335	0,0335	0,0269	0,0388	0,0758
Temperature	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0093	0,0160	0,0117
Temperature dependency	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Polarisation voltage	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022
Insert voltage	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087
Voltage ratio	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087
Type-A	0,0030	0,0057	0,0041	0,0024	0,0037	0,0057	0,0045	0,0036	0,0039	0,0042	0,0045
Combined	0,0542	0,0472	0,0447	0,0445	0,0444	0,0436	0,0437	0,0436	0,0399	0,0593	0,0924
Expanded (k=2), rounded up	0,11	0,10	0,09	0,09	0,09	0,09	0,09	0,09	0,08	0,12	0,19

Uncertainty budget for frequency at 94 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Measurement	0,0014	0,0028	0,0056	0,0113	0,0225	0,0450	0,0900	0,1800	0,3600	0,5625	0,7200
Specification	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010
Combined	0,0017	0,0030	0,0057	0,0113	0,0225	0,0450	0,0900	0,1800	0,3600	0,5625	0,7200
Expanded (k=2), rounded up	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,4	0,8	1,2	1,5

Uncertainty budget for TD+N at 94 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Amplifier chain TD+noise	0,095	0,095	0,095	0,095	0,095	0,095	0,095	0,095	0,095	0,075	0,075
Calibration specification	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,150	0,150
Combined	0,138	0,138	0,138	0,138	0,138	0,138	0,138	0,138	0,138	0,168	0,168
Expanded (k=2), rounded up	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,4

Uncertainty budget for level at 114 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Microphone sensitivity	0,0400	0,0300	0,0250	0,0250	0,0250	0,0250	0,0250	0,0250	0,0250	0,0400	0,0500
Barometric pressure	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0002	0,0003	0,0006
Pressure dependency	0,0303	0,0309	0,0313	0,0310	0,0294	0,0300	0,0302	0,0301	0,0243	0,0360	0,0718
Temperature	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0012	0,0093	0,0160	0,0117
Temperature dependency	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Polarisation voltage	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022
Insert voltage	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087
Voltage ratio	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087	0,0087
Type-A	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011
Combined	0,0517	0,0449	0,0420	0,0417	0,0406	0,0410	0,0412	0,0411	0,0382	0,0575	0,0892
Expanded (k=2), rounded up	0,11	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,08	0,12	0,18

Uncertainty budget for frequency at 114 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Measurement	0,0014	0,0028	0,0056	0,0113	0,0225	0,0450	0,0900	0,1800	0,3600	0,5625	0,7200
Specification	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010
Combined	0,0017	0,0030	0,0057	0,0113	0,0225	0,0450	0,0900	0,1800	0,3600	0,5625	0,7200
Expanded (k=2), rounded up	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,4	0,8	1,2	1,5

Uncertainty budget TD+N at 114 dB setting

Frequency (Hz)	31,5	63	125	250	500	1000	2000	4000	8000	12500	16000
Component (dB)											
Amplifier chain TD+noise	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,018	0,015	0,015
Calibration specification	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,150	0,150
Combined	0,102	0,102	0,102	0,102	0,102	0,102	0,102	0,102	0,102	0,151	0,151
Expanded (k=2), rounded up	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,4

ANNEX C – OUTLIER RESULTS

Results identified as being outliers and that were communicated to NIS.

Table 16. Identified outliers of NIS 94 dB sound pressure level results

SPL range	Frequency	Reported SPL results
94 dB	125	x
	250	x
	500	x
	1 000	x
	2 000	x
	4 000	x
	12 500	x

Table 17. Identified outliers of NIS 114 dB sound pressure level results

SPL range	Frequency	Reported SPL results
114 dB	31.5	x
	63	x
	125	x
	250	x
	500	x
	1 000	x
	2 000	x
	4 000	x
	8 000	x
	12 500	x
	16 000	x

ANNEX D – ACCEPTANCE LIMITS & MAXIMUM-PERMITTED-EXPANDED UNCERTAINTIES

Tables 18. 94 dB Sound pressure level results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated sound pressure level uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail.

94 dB Nominal frequency (Hz)	Sound pressure level acceptance limits (IEC 60942: 2017 Table 2, Class 1)							
	Class 1 (± dB)	94 dB re 20 µPa (dB)						
		Lower limit	Upper limit	NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	0.30	93.70	94.30	93.91	93.93	93.77	93.96	93.97
63	0.30	93.70	94.30	94.01	94.01	93.85	93.99	94.05
125	0.30	93.70	94.30	94.02	94.02	93.83	94.07	94.05
250	0.25	93.75	94.25	94.00	94.02	93.84	94.06	94.03
500	0.25	93.75	94.25	94.01	94.01	93.80	94.03	94.03
1 000	0.25	93.75	94.25	94.02	94.03	93.84	94.04	94.05
2 000	0.35	93.65	94.35	94.06	94.04	93.66	94.06	94.06
4 000	0.35	93.65	94.35	94.01	94.12	93.62	94.05	94.10
8 000	0.45	93.55	94.45	94.03	94.11	93.99	94.18	94.07
12 500	0.50	93.50	94.50	94.23	94.21	93.84	94.35	94.18
16 000	0.50	93.50	94.50	94.02	94.16	94.09	94.17	94.04

94 dB Nominal frequency (Hz)	Sound pressure level maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.1, Class 1)					
	Class 1 (dB)	94 dB sound pressure level				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	0.20	0.06	0.08	0.11	0.15	0.11
63	0.20	0.05	0.08	0.13	0.11	0.10
125	0.20	0.05	0.07	0.08	0.07	0.09
250	0.15	0.05	0.07	0.08	0.07	0.09
500	0.15	0.05	0.07	0.07	0.07	0.09
1 000	0.15	0.05	0.07	0.08	0.07	0.09
2 000	0.25	0.05	0.07	0.12	0.07	0.09
4 000	0.25	0.05	0.07	0.26	0.07	0.09
8 000	0.35	0.05	0.09	0.33	0.11	0.08
12 500	0.50	0.05	0.12	0.26	0.17	0.12
16 000	0.50	0.08	0.12	0.36	0.18	0.19

Tables 19. 114 dB Sound pressure level results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated sound pressure level uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail, White = not evaluated.

114 dB Nominal frequency (Hz)	Sound pressure level acceptance limits (IEC 60942: 2017 Table 2, Class 1)							
	Class 1 (± dB)	114 dB re 20 µPa (dB)						
		Lower limit	Upper limit	NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	0.30	113.70	114.30	113.88	113.88	114.00	113.91	113.90
63	0.30	113.70	114.30	113.99	113.98	114.00	113.96	113.99
125	0.30	113.70	114.30	114.01	114.01	114.00	114.05	114.01
250	0.25	113.75	114.25	114.00	114.00	114.00	114.04	114.00
500	0.25	113.75	114.25	113.99	114.00	114.00	114.02	113.99
1 000	0.25	113.75	114.25	114.01	114.01	114.00	114.03	114.01
2 000	0.35	113.65	114.35	114.05	114.01	114.00	114.04	114.01
4 000	0.35	113.65	114.35	113.97	114.06	114.00	114.00	114.03
8 000	0.45	113.55	114.45	113.99	114.05	114.00	114.13	114.00
12 500	0.50	113.50	114.50	114.03	114.00	114.00	114.14	113.96
16 000	0.50	113.50	114.50	113.68	113.81	114.00	113.84	113.72

114 dB Nominal frequency (Hz)	Sound pressure level maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.1, Class 1)					
	Class 1 (dB)	114 dB sound pressure level				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	0.20	0.06	0.08	0.18	0.15	0.11
63	0.20	0.05	0.08	0.19	0.11	0.09
125	0.20	0.05	0.07	0.16	0.07	0.09
250	0.15	0.05	0.07	0.16	0.07	0.09
500	0.15	0.05	0.07	0.16	0.07	0.09
1 000	0.15	0.05	0.07	0.17	0.07	0.09
2 000	0.25	0.05	0.07	0.18	0.07	0.09
4 000	0.25	0.05	0.07	0.29	0.07	0.09
8 000	0.35	0.05	0.09	0.34	0.11	0.08
12 500	0.50	0.05	0.12	0.20	0.17	0.12
16 000	0.50	0.08	0.12	0.35	0.18	0.15

Tables 20. 94 dB Frequency results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated frequency uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail.

94 dB Expected frequency (Hz)	Frequency acceptance limits (IEC 60942: 2017 Table 4, Class 1)							
	Class 1 (%)	Frequency (Hz)						
		Lower limit	Upper limit	NMISA	GUM	NIS	KEBS	VTT MIKES
31.62	0.7	31.40	31.84	31.63	31.63	31.63	31.6	31.6
63.10	0.7	62.65	63.54	63.13	63.13	63.13	63.1	63.1
125.89	0.7	125.01	126.77	125.88	125.9	125.88	125.9	125.9
251.19	0.7	249.43	252.95	251.27	251.3	251.32	251.3	251.3
501.19	0.7	497.68	504.70	502.54	502.5	502.46	502.5	502.5
1 000.0	0.7	993.0	1 007.0	1 005.1	1 005.1	1 005.0	1 005.1	1 005.1
1 995.3	0.7	1 981.3	2 009.2	1 978.7	1 978.7	1 983.8	1 978.7	1 978.7
3 981.1	0.7	3 953.2	4 008.9	3 957.5	3 957.5	3 960.3	3 957.5	3 957.5
7 943.3	0.7	7 887.7	7 998.9	7 914.9	7 914.9	7 922.3	7 914.9	7 914.9
12 589.3	0.7	12 501.1	12 677.4	12 663.9	12 663.9	12 660.2	12 663.9	12 663.9
15 848.9	0.7	15 738.0	15 959.9	15 829.9	15 829.9	15 842.0	15 829.8	15 829.8

94 dB Expected frequency (Hz)	Frequency maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.2, Class 1)						
	Class 1		Frequency (Hz)				
	(%)	(Hz)	NMISA	GUM	NIS	KEBS	VTT MIKES
31.62	0.2	0.22	0.01	0.05	0.008	0.1	0.1
63.10	0.2	0.44	0.02	0.05	0.008	0.1	0.1
125.89	0.2	0.88	0.04	0.1	0.028	0.3	0.1
251.19	0.2	1.76	0.08	0.1	0.028	0.5	0.1
501.19	0.2	3.51	0.15	0.1	0.045	1.0	0.1
1 000.0	0.2	7.0	0.3	0.1	0.298	2.0	0.1
1 995.3	0.2	14.0	0.6	0.1	0.267	4.0	0.2
3 981.1	0.2	27.9	1.2	0.1	0.427	8.0	0.4
7 943.3	0.2	55.6	2.4	0.1	0.427	15.9	0.8
12 589.3	0.2	88.1	3.8	0.1	0.400	25.2	1.2
15 848.9	0.2	110.9	4.8	0.2	2.667	31.7	1.5

Tables 21. 114 dB Frequency results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated frequency uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail.

114 dB Expected frequency (Hz)	Frequency acceptance limits (IEC 60942: 2017 Table 4, Class 1)							
	Class 1 (%)	Frequency (Hz)						
		Lower limit	Upper limit	NMISA	GUM	NIS	KEBS	VTT MIKES
31.62	0.7	31.40	31.84	31.63	31.63	31.63	31.6	31.6
63.10	0.7	62.65	63.54	63.13	63.13	63.13	63.1	63.1
125.89	0.7	125.01	126.77	125.88	125.9	125.89	125.9	125.9
251.19	0.7	249.43	252.95	251.27	251.3	251.3	251.3	251.3
501.19	0.7	497.68	504.70	502.54	502.5	502.49	502.5	502.5
1 000.0	0.7	993.0	1 007.0	1 005.1	1 005.1	1 004.9	1 005.1	1 005.1
1 995.3	0.7	1 981.3	2 009.2	1 978.7	1 978.7	1 983.8	1 978.7	1 978.7
3 981.1	0.7	3 953.2	4 008.9	3 957.5	3 957.5	3 959.9	3 957.5	3 957.5
7 943.3	0.7	7 887.7	7 998.9	7 914.9	7 914.9	7 921.9	7 914.9	7 914.9
12 589.3	0.7	12 501.1	12 677.4	12 663.9	12 663.9	12 657.5	12 663.9	12 663.9
15 848.9	0.7	15 738.0	15 959.9	15 829.9	15 829.9	15 840.5	15 829.8	15 829.8

114 dB Expected frequency (Hz)	Frequency maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.2, Class 1)						
	Class 1		Frequency (Hz)				
	(%)	(Hz)	NMISA	GUM	NIS	KEBS	VTT MIKES
31.62	0.2	0.22	0.01	0.05	0.008	0.1	0.1
63.10	0.2	0.44	0.02	0.05	0.008	0.1	0.1
125.89	0.2	0.88	0.04	0.1	0.013	0.3	0.1
251.19	0.2	1.76	0.08	0.1	0.017	0.5	0.1
501.19	0.2	3.51	0.15	0.1	0.013	1.0	0.1
1 000.0	0.2	7.0	0.3	0.1	0.100	2.0	0.1
1 995.3	0.2	14.0	0.6	0.1	0.134	4.0	0.2
3 981.1	0.2	27.9	1.2	0.1	0.100	8.0	0.4
7 943.3	0.2	55.6	2.4	0.1	0.100	15.9	0.8
12 589.3	0.2	88.1	3.8	0.1	0.670	25.2	1.2
15 848.9	0.2	110.9	4.8	0.2	0.500	31.7	1.5

Tables 22. 94 dB TD+N results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated TD+N uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail.

94 dB Nominal frequency (Hz)	Maximum total distortion + noise (IEC 60942: 2017 Table 7, Class 1)					
	Class 1 (%)	TD+N (%)				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	3.0	0.50	0.5	0.44	1.5	0.9
63	3.0	0.17	0.2	0.03	0.7	0.6
125	3.0	0.15	0.3	0.05	0.6	0.6
250	2.5	0.18	0.4	0.07	1.6	0.6
500	2.5	0.33	0.5	0.07	0.9	0.7
1 000	2.5	0.40	0.5	0.18	0.5	0.7
2 000	3.0	0.45	0.6	0.30	0.5	0.8
4 000	3.0	0.68	0.7	0.55	1.0	0.9
8 000	3.0	0.40	0.5	0.20	0.4	0.7
12 500	3.0	0.32	0.4	0.07	0.6	0.5
16 000	3.0	0.30	0.4	0.10	0.5	0.6

94 dB Nominal frequency (Hz)	Total distortion + noise maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.3, Class 1)					
	Class 1 (%)	TD+N (%)				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	1.0	0.30	0.2	0.056	0.50	0.3
63	1.0	0.30	0.2	0.056	0.50	0.3
125	1.0	0.30	0.2	0.056	0.50	0.3
250	0.5	0.30	0.2	0.061	0.50	0.3
500	0.5	0.30	0.2	0.056	0.50	0.3
1 000	0.5	0.30	0.2	0.056	0.50	0.3
2 000	1.0	0.30	0.2	0.090	0.50	0.3
4 000	1.0	0.30	0.2	0.075	0.50	0.3
8 000	1.0	0.30	0.2	0.063	0.50	0.3
12 500	1.0	0.30	0.2	0.056	0.50	0.4
16 000	1.0	0.30	0.2	0.057	0.50	0.4

Tables 23. 114 dB TD+N results evaluated against IEC 60942: 2017 periodic testing acceptance limits (left). Associated TD+N uncertainties evaluated against IEC 60942: 2017 periodic testing maximum-permitted uncertainty of measurement (right). Green = Pass, Red = Fail.

114 dB Nominal frequency (Hz)	Maximum total distortion + noise (IEC 60942: 2017 Table 7, Class 1)					
	Class 1 (%)	TD+N (%)				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	3.0	0.31	0.2	0.29	0.3	0.3
63	3.0	0.13	0.2	0.13	0.1	0.1
125	3.0	0.09	0.2	0.08	0.1	0.1
250	2.5	0.08	0.1	0.07	0.1	0.1
500	2.5	0.15	0.2	0.05	0.1	0.1
1 000	2.5	0.24	0.2	0.19	0.1	0.2
2 000	3.0	0.31	0.3	0.30	0.1	0.3
4 000	3.0	1.31	1.3	1.27	1.4	1.4
8 000	3.0	0.25	0.3	0.18	0.1	0.2
12 500	3.0	0.09	0.1	0.05	0.1	0.1
16 000	3.0	0.11	0.2	0.14	0.1	0.1

114 dB Nominal frequency (Hz)	Total distortion + noise maximum-permitted uncertainty of measurement (k = 2) (IEC 60942: 2017 Table A.3, Class 1)					
	Class 1 (%)	TD+N (%)				
		NMISA	GUM	NIS	KEBS	VTT MIKES
31.5	1.0	0.30	0.2	0.056	0.5	0.3
63	1.0	0.30	0.2	0.056	0.5	0.3
125	1.0	0.30	0.2	0.055	0.5	0.3
250	0.5	0.30	0.2	0.055	0.5	0.3
500	0.5	0.30	0.2	0.055	0.5	0.3
1 000	0.5	0.30	0.2	0.055	0.5	0.3
2 000	1.0	0.30	0.2	0.056	0.5	0.3
4 000	1.0	0.30	0.2	0.060	0.5	0.3
8 000	1.0	0.30	0.2	0.056	0.5	0.3
12 500	1.0	0.30	0.2	0.055	0.5	0.4
16 000	1.0	0.30	0.2	0.058	0.5	0.4