REPORT ON KEY COMPARISON APMP.AUV.A–K3

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Abstract

A regional key-comparison APMP.AUV.A–K3 has been carried out for the pressure sensitivity of laboratory standard microphones. The Korea Research Institute of Standards and Science (KRISS) was the pilot laboratory for this project. Two LS2P microphones were circulated through ten national metrology institutes and calibrated in the frequency range from 31.5 Hz to 25 kHz (31.5 kHz was optional). Deviations from the mean value for all participants are within their declared expanded uncertainties for all frequencies except the optional 31.5 kHz. The results will be linked to the CIPM key comparison CCAUV.A–K3 in a separate report.

1. Introduction

This is the final report for the regional key-comparison APMP.AUV.A–K3. It has taken into account the comments from the participants and has been approved by them. It has also been approved by the CCAUV.

This report includes calibration results from the participants and an outline of proposed linking to the CIPM key-comparison CCAUV.A–K3 [1]. The Korea Research Institute of Standards and Science (KRISS) prepared this report as the pilot laboratory.

2. Protocol

The basis of this key-comparison was pressure calibration of laboratory standard microphones. Two LS2P microphones, a Bruel & Kjaer type 4180 with serial number 1763688 and a Bruel & Kjaer type 4180 with serial number 2341431 were supplied by KRISS.

A technical protocol instructed participants to submit their uncertainty budget prior to the key comparison and then to report the pressure sensitivity in the frequency range from 31.5 Hz to 25 kHz (31.5 kHz was optional) and at the reference environmental conditions in their usual certificate forms. Additional information was requested on any deviation from the requirements of IEC 61094-2, together with the estimated uncertainty.

Ten national metrology institutes took part in the project, as listed in Table 1.

Table 1. Participants in the key-comparison APMP.AUV.A–K3.

Participant	Acronym	Economy
National Institute of Metrology (Thailand)	NIMT	Thailand
Center for Measurement Standards Industrial Technology Research Institute	CMS/ITRI	Taiwan
National Measurement Institute (Australia)	NMIA	Australia
National Physical Laboratory of India	NPLI	India
Standards and Calibration Laboratory	SCL	Hong Kong
National Metrology Laboratory SIRIM Berhad	NML/SIRIM	Malaysia
National Metrology Institute of Japan	NMIJ	Japan
National Institute of Metrology	NIM	China
National Metrology Centre Agency for Science, Technology and Research, Singapore	NMC	Singapore
Korea Research Institute of Science and Standards	KRISS	Korea

2.1. Circulation of the microphones

This key comparison permitted international delivery services for the transportation of the microphones. Therefore KRISS paid close attention to their travelling container. The container was supplied by NMIJ and previously used in key comparison APMP.AUV.A–K1. The microphones were packaged in an aluminum box padded with cushioning material and containing small holes in the outside casing to avoid sudden shocks and to minimize extreme changes in temperature or pressure, which could cause an irreversible change in the sensitivity or degrade the stability of the microphones. The KRISS also recommended a reliable shipping agency that had handled other kinds of travelling standards previously.

Microphones were circulated from July 2006 to June 2007 and returned to the KRISS for a check calibration each time two participants completed their calibrations. The circulation proceeded exactly as planned due to the participants' cooperation.

2.2. Measurement frequencies

The protocol specified the calibration of the microphones at the nominal frequencies as in the CCAUV.A–K3; the nominal preferred octave frequencies from 31.5 Hz to 4 kHz (i.e. 31.5, 63.0, 125.0, 250.0, 500.0, 1000.0, 2000.0 and

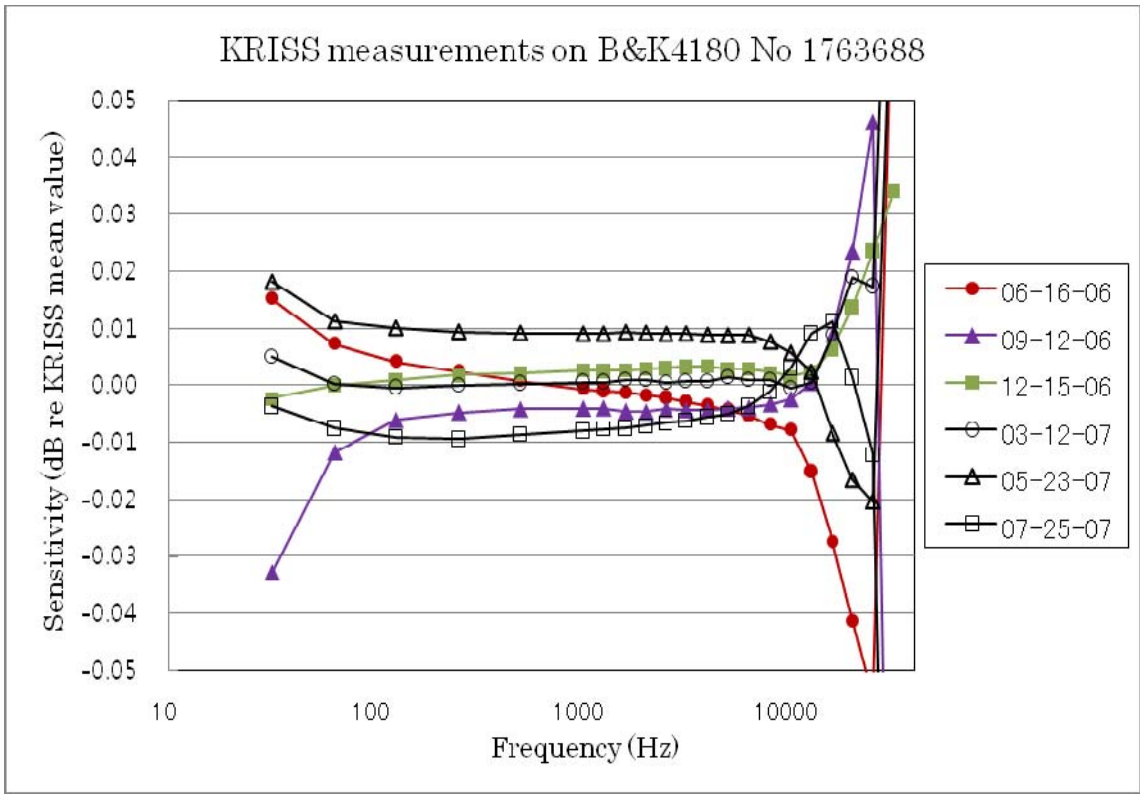
4000.0 Hz) and the nominal preferred 1/3 octave frequencies from 6.3 kHz to 25 kHz (i.e. 6.3, 8.0, 10.0, 12.5, 16.0, 20.0 and 25.0 kHz). The 31.5 kHz frequency was optional. Experience in the CIPM key comparison CCAUV.A–K3 showed that the set of frequencies to be used should be specified clearly [1] and this improvement proved to be largely effective in this key comparison.

3. Travelling standards

The KRISS regularly monitored the stability of the microphones on their return to the pilot laboratory. Fig. 1 shows the deviation of each calibration from the average value at the KRISS. Observed changes over the period are well below the uncertainty quoted by the KRISS, thus confirming that the microphones had an acceptable level of stability during the circulation.

Therefore the very first measurement from the KRISS was used as the reported KRISS result for this key comparison. This practice follows previous CCAUV key comparisons.

Fig. 2 gives the temporal variation of the sensitivities at 250 Hz. For reference, results declared by the participants are included. There appears to be little significant correlation between the stability of the microphones and the results from participants.



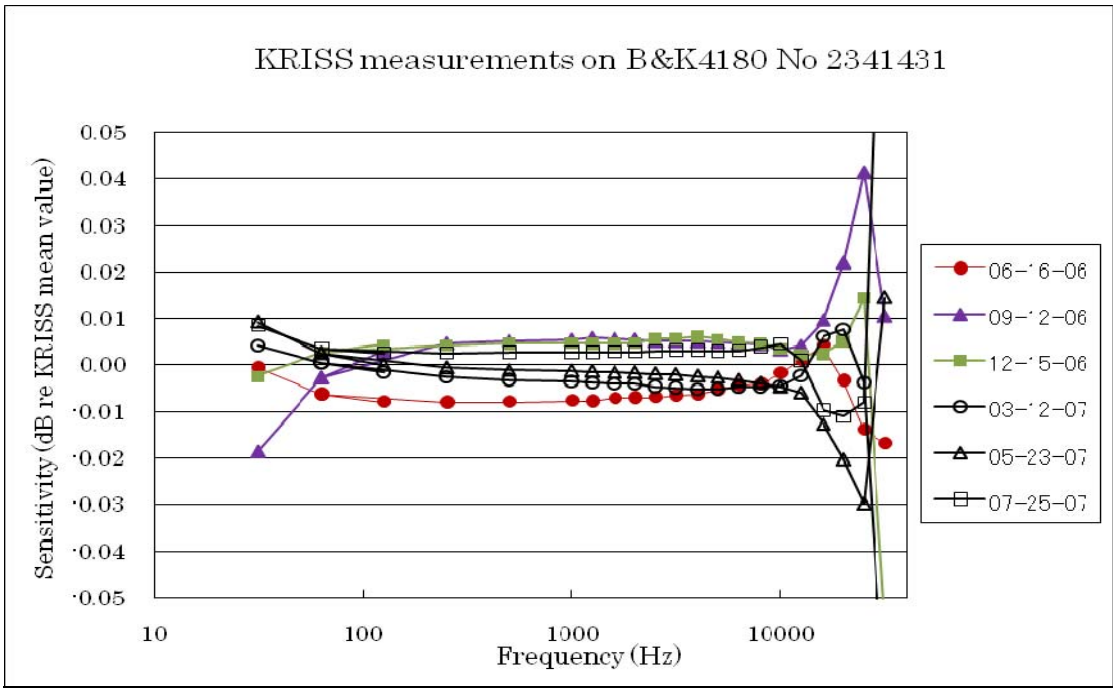


Fig. 1. KRISS measurements during APMP.AUV.A-K3.

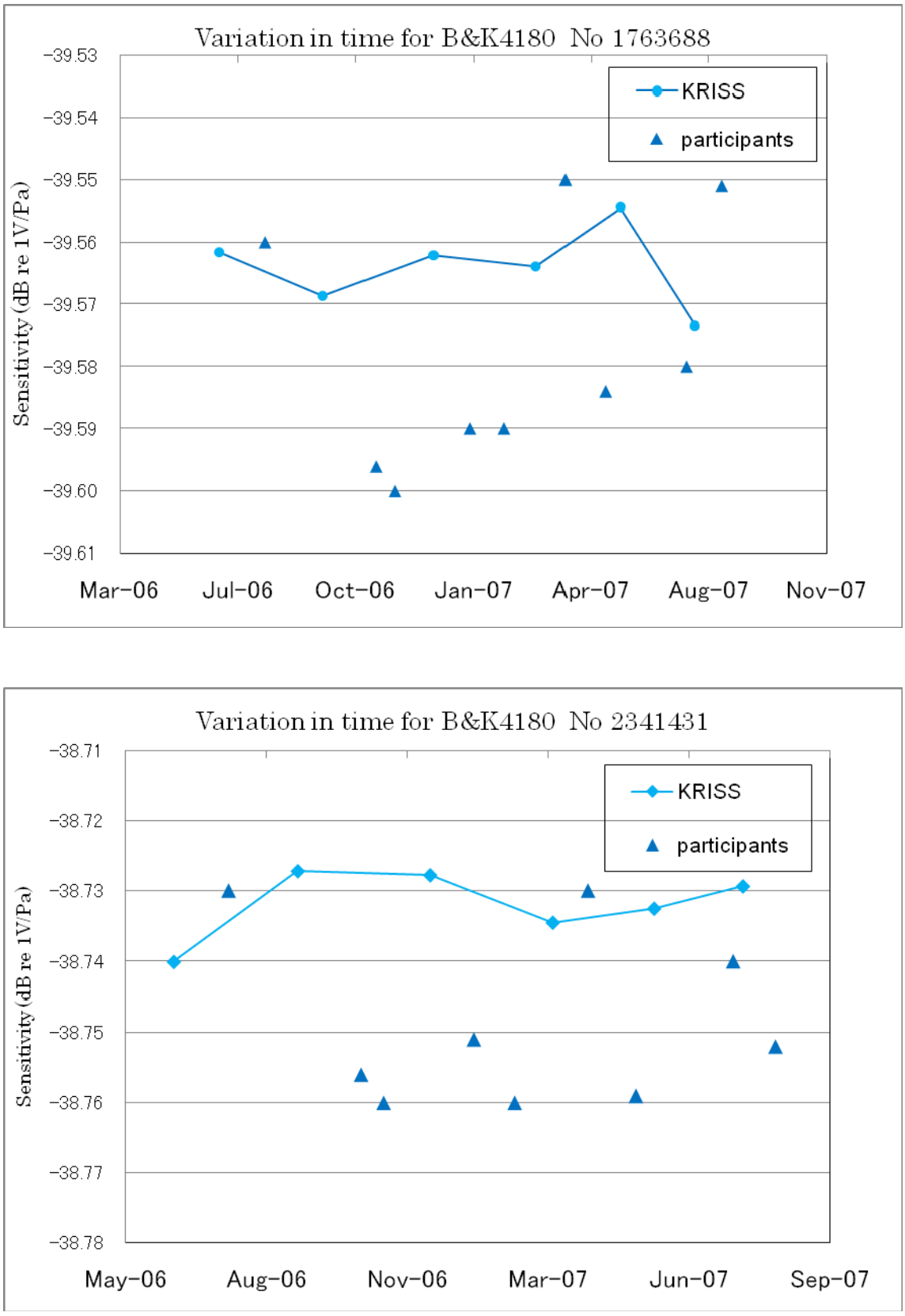


Fig. 2. Sensitivity variation during APMP.AUV.A-K3 at 250 Hz.

4. Methodologies

The protocol required that the calibration method should be based on IEC 61094-2, but this Standard does not mention any specific equipment to be used. The following descriptions give the methodologies and facilities used in this key comparison by each participant. Any variation from the requirements of IEC 61094-2 was also included, if declared.

NIMT – The NIMT used the reciprocity calibration system. In this system, the voltage transfer function was measured using the insert voltage technique. The transmitter current was determined by measuring the voltage across a calibrated capacitance connected in series with the transmitter.

Two plain wave couplers (cavity volume 3.098 cm^3 and 5.135 cm^3 respectively) were used, filled with air at all measurement frequencies. The microphones were set into the coupler without using grease on the assumption that leakage of air and sound was negligible. Capillary tube correction was not applied because a needle bung was fitted with each coupler instead of the capillary tube. The needle bung was attached to the coupler to equalize the static pressure and to act as an acoustic seal. No corrections were applied.

CMS/ITRI – The CMS/ITRI used two reference microphones and one microphone to be calibrated by selecting two microphones a group to carry out the calibration, one being as the transmitting microphone and the other as the receiving microphone during calibration. They placed the microphones separately into the cavity coupler and measured the ratio of voltage attenuation, thus obtaining three individual sets of sensitivity equations to solve the sound pressure sensitivity of microphone under calibration by the reciprocity method.

NMIA - Pressure sensitivity by the reciprocity technique was determined using 3 type LS2P laboratory standard microphones according to IEC 61094-2. The measurement data was analysed using the computer software MP.EXE microphone pressure sensitivity calibration program. The radial wave motion corrections were applied. Three different plane wave couplers of nominal lengths of 3 mm, 4 mm and 6 mm with maximum frequency limits of

31.5 kHz, 25 kHz and 16 kHz respectively were utilized and the results averaged in their overlapping frequency range.

The front cavity volume, equivalent volume and resonance frequency were determined by data fitting. The front cavity depth was measured using a microscope fitted with an electronic depth gauge and the damping factor was determined from the ratio of the sensitivities where they are at maxima and in the vicinity of 1000 Hz where they level out.

NPLI - The capacitor microphones were calibrated by absolute method in the frequency range 31.5 Hz to 25 kHz using plane wave couplers. Using three standard microphones in successive pairs the open-circuit voltage sensitivities of the microphones were obtained by using reciprocity calibration. The microphones were acoustically coupled in pairs by the air enclosed in a coupler. For each pair, one microphone was used as a sound source (transmitter) and the other as a receiver. The task was to measure the electrical transfer impedance U_R/i_T where U_R is the open circuit voltage of the receiver microphone and i_T is the current through the transmitter microphone. The current through the transmitter microphone was found by measuring the voltage across a reference capacitor connected in series with the microphone. The measurements were controlled by PC software running on the Windows platform. For each frequency five sets of measurements were made and the measurement data was stored in a text file along with microphone identification and ambient parameters. Using this information the calculation program calculates the sensitivities of the three microphones in accordance with IEC-61094-2. Also the sensitivities valid at reference ambient conditions (Room Temperature T = 23 °C, Static Pressure P_s = 101.325 kPa and Relative Humidity RH = 50%) were calculated through the use of built-in microphone correction data. To increase the accuracy, repeated calibrations were made using different couplers thus allowing the determination of the total volume along with other microphone parameters by an iterative process giving convergent results.

SCL - The open circuit pressure sensitivity of the microphone was determined by reciprocity technique in accordance with the international standard IEC 61094-2:1992. A long plane wave and a short plane wave coupler were used in the measurement. For the frequencies 31.5 Hz to

2000 Hz, both the long and short couplers were used. The measurement results reported in the certificate for the frequency range from 31.5 Hz to 2000 Hz were the average of the two results. For frequencies above 2000 Hz, only the short plane wave coupler was used.

NML/SIRIM - Absolute calibration method using Reciprocity Calibration System according to IEC 61094-2:1992 was used. The open circuit sensitivities of the microphones are obtained by using a combination of reciprocity calibration and insert voltage techniques. The microphones are acoustically coupled in pairs by the air enclosed in a coupler. There are two couplers (short and long) used in this measurement with precisely determined dimensions. For each pair of microphones, one microphone is used as a sound source (transmitter), and the other as a receiver. Included with the system are two PC programs, one to control measurements and the other to handle the sensitivity calculations according to the IEC Standard.

NMIJ - The pressure sensitivity was determined in compliance with IEC 61094-2, using a reciprocity calibration system developed by NMIJ. In the system, both the signal generation and the signal processing were executed by a dual-channel FFT analyzer, model CF-5220 of ONO SOKKI Co. Signal to noise ratio was improved by the synchronous waveform averaging method. The insert voltage technique was used to cancel the effect of the gain and impedance of an electrical circuit. The calibration was performed by using software of our own making.

A Brüel & Kjær UA1430 plane-wave (short) coupler was used for the reciprocity calibration and a long coupler type UA1414 was also used for determining the equivalent volume of the microphones under test. Both couplers were filled with air and no grease was used to the contacting surfaces between the microphones and the coupler. Capillary tube correction was considered to be unnecessary because a capillary tube was blocked by a needle bung DA5563 so that both equalization of static pressure and an acoustic seal could be ensured. Correction for radial wave-motion was not applied either.

All the measurements were conducted within a room whose temperature and relative humidity were controlled (23.0 ± 0.5 ℃ and 50 ± 5 %RH, respectively). The sensitivity was corrected to the reference environmental

conditions by using K. Rasmussen's method [2]. At 31.5 kHz, only pressure dependency has been corrected because of the lack of a reliable temperature coefficient.

Microphone parameters were determined as follows: The resonance frequency, loss factor and the cavity volume of the couplers were taken from Brüel & Kjær's nominal values. Front depth was measured using a microscope calibrated by a block gauge. Equivalent volume was calculated as an averaged value from 250 Hz to 4 kHz.

NIM - Conforming to the Reference Standard IEC 61094-2 Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique, NIM carried out six complete measurements. The Reciprocity calibration system and the computer software MP.EXE determined the open-circuit pressure sensitivity of the microphones. The front cavity depth of the microphones was determined by using an optical method, and then the front volume calculated. The loss factor, pressure coefficient and temperature coefficient that we used were the typical values of the microphone. Equivalent volume was determined by analysis of the measurement curve using the software MP.EXE. Two plane wave couplers were used during measurements and coupler parameters that we used were also the typical values.

NMC - Before the measurements, the microphones were conditioned in the laboratory for 24 hours. The 200 volt polarisation voltage was measured and adjusted to within ± 0.01 V during test set-up, and was verified again after all the measurements were completed. A precision pressure sensor was used to monitor static pressure inside the measurement chamber during measurement.

The measurements were made according to IEC 61094-2 using Brüel & Kjær Reciprocity Calibration System Type 9699. Two reference microphones were paired with the two microphones under comparison. A short coupler (4.7 mm) was used for measuring the pressure sensitivities in the frequency range of 31 Hz to 25 kHz, and a long coupler (9.4 mm) was used for the frequency range of 31 Hz to 2 kHz. The measurement result for each frequency point was obtained by averaging the pressure sensitivities measured using the short and long couplers at the same frequency.

In the calculation of pressure sensitivities for the standard with serial

number 1763688, nominal values for microphone parameters were used. For the standard with serial number 2341431, measured values provided by Brüel & Kjær (B&K) were used in the calculation.

KRISS - The calibration is performed by reciprocity calibration according to IEC 61094-2 using three reciprocal microphones. The microphones are coupled in pairs with two plane-wave couplers of different length (nominal length: 4.7 mm and 9.4 mm).

The receiver microphone is connected to a preamplifier B&K type 2673/WH 3291 with insert voltage facilities and the transmitter microphone is connected to a similar housing but with grounded shield.

The electrical current through the transmitter is measured as the voltage across the 4.7 nF capacitor connected in series with the transmitter. The measuring instruments are: Sine Generator B&K 1051, Digital Multimeter Wavetek 1281 and 1/3 Octave band Pass Filter B&K 1617. The measurements are made at discrete frequencies controlled via computer.

During the calibrations the coupler and the microphones are located under a cylindrical bulb of volume of about 20 litre and the cylindrical bulb is again enclosed by the acryl box with dimensions of 650 mm(W) × 859 mm(H) × 700 mm(D). The static pressure is measured using a Multifunction Pressure Indicator, Druck DPI 145, the temperature and the relative humidity are measured using a Testo 650.

The front cavity depths of the microphones are measured using the Video Measuring Scope, Nikon, VMH-300N. The equivalent volume is determined by fitting the final results for the two couplers in the frequency range up to about 2 kHz. Nominal values are assumed for the resonance frequency and the loss factor of the microphone diaphragm.

5. Results

The pressure sensitivities of the two microphones determined by each participant are shown in Table 2. They are presented with two or three decimals, depending on the way they were reported. Table 3 gives the associated measurement uncertainties. For the optional 31.5 kHz frequency, only three participants reported their results. The SCL did not measure the pressure sensitivity at 6300 Hz.

Table 2 (a). Pressure sensitivity (dB re 1 V/Pa) for B&K 4180 No 1763688.

Freq. (Hz)	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	-39.53	-39.55	-39.571	-39.58	-39.559	-39.52	-39.58	-39.558	-39.520	-39.558
63	-39.54	-39.56	-39.583	-39.58	-39.573	-39.54	-39.58	-39.568	-39.534	-39.553
125	-39.55	-39.57	-39.589	-39.59	-39.583	-39.54	-39.59	-39.574	-39.543	-39.559
250	-39.56	-39.58	-39.596	-39.60	-39.590	-39.55	-39.59	-39.584	-39.551	-39.564
500	-39.56	-39.58	-39.601	-39.60	-39.594	-39.55	-39.60	-39.588	-39.556	-39.567
1000	-39.56	-39.58	-39.600	-39.60	-39.594	-39.55	-39.59	-39.588	-39.555	-39.566
2000	-39.55	-39.56	-39.582	-39.58	-39.575	-39.53	-39.58	-39.569	-39.539	-39.547
4000	-39.46	-39.48	-39.501	-39.50	-39.495	-39.46	-39.50	-39.488	-39.450	-39.461
6300	-39.31	-39.33	-39.352	-39.34	–	-39.32	-39.35	-39.337	-39.305	-39.310
8000	-39.18	-39.18	-39.216	-39.19	-39.214	-39.19	-39.22	-39.201	-39.179	-39.172
10000	-39.02	-39.01	-39.049	-39.04	-39.049	-39.04	-39.06	-39.032	-39.019	-39.010
12500	-38.88	-38.83	-38.886	-38.85	-38.891	-38.89	-38.91	-38.866	-38.874	-38.858
16000	-38.94	-38.92	-38.907	-38.93	-38.946	-38.97	-38.95	-38.933	-38.918	-38.932
20000	-39.68	-39.67	-39.658	-39.67	-39.703	-39.75	-39.64	-39.675	-39.660	-39.695
25000	-41.52	-41.63	-41.620	-41.66	-41.684	-41.69	-41.51	-41.540	-41.681	-41.770
31500	–	–	-44.793	–	–	–	-46.46	–	–	-45.835

Table 2 (b). Pressure sensitivity (dB re 1 V/Pa) for B&K 4180 No 2341431.

Freq. (Hz)	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	-38.70	-38.72	-38.748	-38.76	-38.728	-38.71	-38.73	-38.744	-38.730	-38.727
63	-38.71	-38.73	-38.752	-38.76	-38.743	-38.72	-38.75	-38.755	-38.744	-38.725
125	-38.73	-38.74	-38.756	-38.76	-38.751	-38.73	-38.76	-38.759	-38.752	-38.728
250	-38.73	-38.74	-38.760	-38.77	-38.757	-38.73	-38.76	-38.769	-38.758	-38.732
500	-38.74	-38.75	-38.762	-38.77	-38.759	-38.73	-38.76	-38.771	-38.760	-38.733
1000	-38.73	-38.74	-38.758	-38.76	-38.757	-38.73	-38.76	-38.769	-38.757	-38.729
2000	-38.71	-38.72	-38.734	-38.74	-38.732	-38.71	-38.73	-38.744	-38.733	-38.703
4000	-38.59	-38.61	-38.629	-38.63	-38.628	-38.60	-38.63	-38.639	-38.632	-38.593
6300	-38.40	-38.41	-38.432	-38.44	–	-38.41	-38.43	-38.440	-38.432	-38.395
8000	-38.22	-38.22	-38.251	-38.24	-38.253	-38.24	-38.25	-38.255	-38.258	-38.211
10000	-37.99	-37.99	-38.025	-38.02	-38.028	-38.02	-38.03	-38.026	-38.024	-37.992
12500	-37.78	-37.76	-37.806	-37.78	-37.811	-37.82	-37.82	-37.797	-37.799	-37.778
16000	-37.86	-37.88	-37.867	-37.87	-37.893	-37.92	-37.89	-37.879	-37.850	-37.873
20000	-38.93	-38.95	-38.918	-38.90	-38.981	-39.00	-38.92	-38.934	-38.902	-38.906
25000	-41.44	-41.49	-41.443	-41.33	-41.534	-41.53	-41.44	-41.414	-41.511	-41.357
31500	–	–	-45.023	–	–	–	-46.16	–	–	-46.118

Table 3. Declared expanded uncertainties at $k = 2$ (dB).

Freq. (Hz)	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	0.06	0.04	0.08	0.12	0.08	0.04	0.06	0.08	0.06	0.08
63	0.04	0.04	0.06	0.11	0.04	0.04	0.06	0.05	0.04	0.05
125	0.04	0.04	0.05	0.08	0.04	0.04	0.06	0.05	0.04	0.05
250	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05	0.04	0.04
500	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.04
1000	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.04
2000	0.04	0.04	0.04	0.08	0.04	0.04	0.05	0.05	0.04	0.04
4000	0.04	0.04	0.04	0.08	0.04	0.04	0.05	0.05	0.04	0.04
6300	0.04	0.04	0.04	0.10	–	0.04	0.05	0.05	0.04	0.04
8000	0.04	0.04	0.04	0.10	0.04	0.04	0.05	0.05	0.04	0.04
10000	0.04	0.06	0.05	0.11	0.04	0.05	0.05	0.05	0.04	0.05
12500	0.04	0.08	0.06	0.11	0.04	0.06	0.06	0.10	0.05	0.06
16000	0.05	0.08	0.08	0.12	0.05	0.07	0.07	0.10	0.06	0.07
20000	0.08	0.08	0.10	0.13	0.08	0.10	0.13	0.10	0.09	0.10
25000	0.14	0.12	0.15	0.17	0.14	0.17	0.18	0.12	0.15	0.20
31500	–	–	0.25	–	–	–	0.66	–	–	1.00

Every participant declared the same uncertainties for each microphone. Detailed uncertainty budgets for the participants are reproduced in Appendix A.

Microphone parameters are listed in Table 4, and temperature and pressure coefficients of the sensitivity in Table 5. Every participant submitted the same coefficients for each microphone. These coefficients are frequency dependent, but most of the participants reported just a single value. In this case, the pilot laboratory regarded the reported coefficients as the values at 250 Hz, if not specified. Furthermore, information on the couplers used in the key comparison is described in Table 6.

Table 4 (a). Microphone parameters for B&K4180 No 1763688.

	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
Front cavity volume /mm^3	32.759	33.1	32.0	34	33.3	34	32.6	32.7	34	35
Front cavity depth /mm	0.488	0.48	0.482	0.463	0.5	0.5	0.48	0.479	0.5	0.505
Equivalent volume /mm^3	9.2	6.6	8.1	7.56	7.1	9.2	8.1	7.9	9.2	6.7
Resonance freq. /kHz	22	22	23.0	22.4	23	22	22	22	22	22
Loss factor	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05

Table 4 (b). Microphone parameters for B&K4180 No 2341431.

	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
Front cavity volume /mm^3	33.818	33.4	33.0	32.8	33.6	34	33.2	32.9	33.3	33.1
Front cavity depth /mm	0.507	0.48	0.498	0.504	0.5	0.5	0.49	0.479	0.496	0.478
Equivalent volume /mm^3	9.2	7.5	8.5	9.64	8	9.2	9.1	8.2	8.1	10.1
Resonance freq. /kHz	22	22	22.0	22.4	23	22	22	22	22	22
Loss factor	1.05	1.05	1.05	1.07	1.05	1.05	1.05	1.05	1.05	1.05

Table 5 (a). Temperature coefficients for pressure sensitivity (dB/K).

Freq. /Hz	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	-0.001	–	–	–	–	–	-0.002	–	–	-0.001
63	-0.001	–	–	–	–	–	-0.002	–	–	-0.001
125	-0.001	–	–	–	–	–	-0.002	–	–	-0.001
250	-0.001	-0.002	-0.002	-0.0012	-0.002	-0.002	-0.002	-0.002	-0.0012	-0.001
500	-0.001	–	–	–	–	–	-0.002	–	–	-0.001
1000	-0.001	–	–	–	–	–	-0.002	–	–	-0.001
2000	-0.002	–	–	–	–	–	-0.003	–	–	-0.002
4000	-0.003	–	–	–	–	–	-0.003	–	–	-0.003
6300	-0.005	–	–	–	–	–	-0.006	–	–	-0.005
8000	-0.007	–	–	–	–	–	-0.008	–	–	-0.007
10000	-0.010	–	–	–	–	–	-0.011	–	–	-0.011
12500	-0.014	–	–	–	–	–	-0.014	–	–	-0.015
16000	-0.015	–	–	–	–	–	-0.017	–	–	-0.016
20000	-0.009	–	–	–	–	–	-0.008	–	–	-0.008
25000	0.006	–	–	–	–	–	0.009	–	–	0.006
31500	–	–	–	–	–	–	–	–	–	0.012

Table 5 (b). Pressure coefficients for pressure sensitivity (dB/kPa).

Freq. /Hz	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	-0.005	–	–	–	–	–	-0.006	–	–	-0.005
63	-0.005	–	–	–	–	–	-0.006	–	–	-0.005
125	-0.005	–	–	–	–	–	-0.006	–	–	-0.005
250	-0.005	-0.0055	-0.0055	-0.0055	-0.007	-0.007	-0.006	-0.0055	-0.0064	-0.006
500	-0.005	–	–	–	–	–	-0.006	–	–	-0.006
1000	-0.005	–	–	–	–	–	-0.006	–	–	-0.006
2000	-0.005	–	–	–	–	–	-0.005	–	–	-0.005
4000	-0.003	–	–	–	–	–	-0.004	–	–	-0.004
6300	-0.001	–	–	–	–	–	-0.001	–	–	-0.001
8000	0.002	–	–	–	–	–	0.001	–	–	0.002
10000	0.006	–	–	–	–	–	0.005	–	–	0.005
12500	0.008	–	–	–	–	–	0.008	–	–	0.008
16000	-0.001	–	–	–	–	–	0.004	–	–	0.001
20000	-0.019	–	–	–	–	–	-0.017	–	–	-0.021
25000	-0.046	–	–	–	–	–	-0.043	–	–	-0.046
31500	–	–	–	–	–	–	-0.048	–	–	-0.049

Table 6. Information on the couplers.

(a) short plane-wave coupler

	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
Diameter /mm	9.3	9.3	9.3	–	9.3	9.3057	9.3	–	9.30729	9.3
Length /mm	4.7	4.7	3.0, 4.0	–	4.7	4.7019	4.7	–	4.69958	4.7
Freq. Range /Hz	20 to 25k	20 to 25k	20 to -31.5k, -25k	–	31.5 to 25k	20 to 25k	31.5 to 31.5k	–	31 to 25k	20 to 25k

(b) long plane-wave coupler

	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
Diameter /mm	9.3	9.3	9.3	–	9.3	9.3	9.3	–	9.30488	9.3
Length /mm	9.4	9.4	6.0	–	9.4	9.4	9.4	–	9.40285	9.4
Freq. Range /Hz	20 to 13k	20 to 13k	20 to 16k	–	31.5 to 2k	20 to 13k	250 to 4k	–	31 to 2k	20 to 13k

(c) capillary tube

	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
Number	–	0	none	–	none	none	none	–	–	–
Inner diameter /mm	–	0.335	–	–	–	–	–	–	–	–
Length /mm	–	50	–	–	–	–	–	–	–	–

For each of the two microphones and at each of the frequencies, the mean value of the pressure sensitivity level was determined from all the submitted data. Fig. 3 shows the results of individual participants expressed as the difference from this mean value.

Fig. 3 indicates that the trend for each participant is mostly common to both microphones, as observed in the CCAUV.A–K3. Therefore the average difference for the two microphones was taken to specify the performance of each participant and presented in Fig. 4.

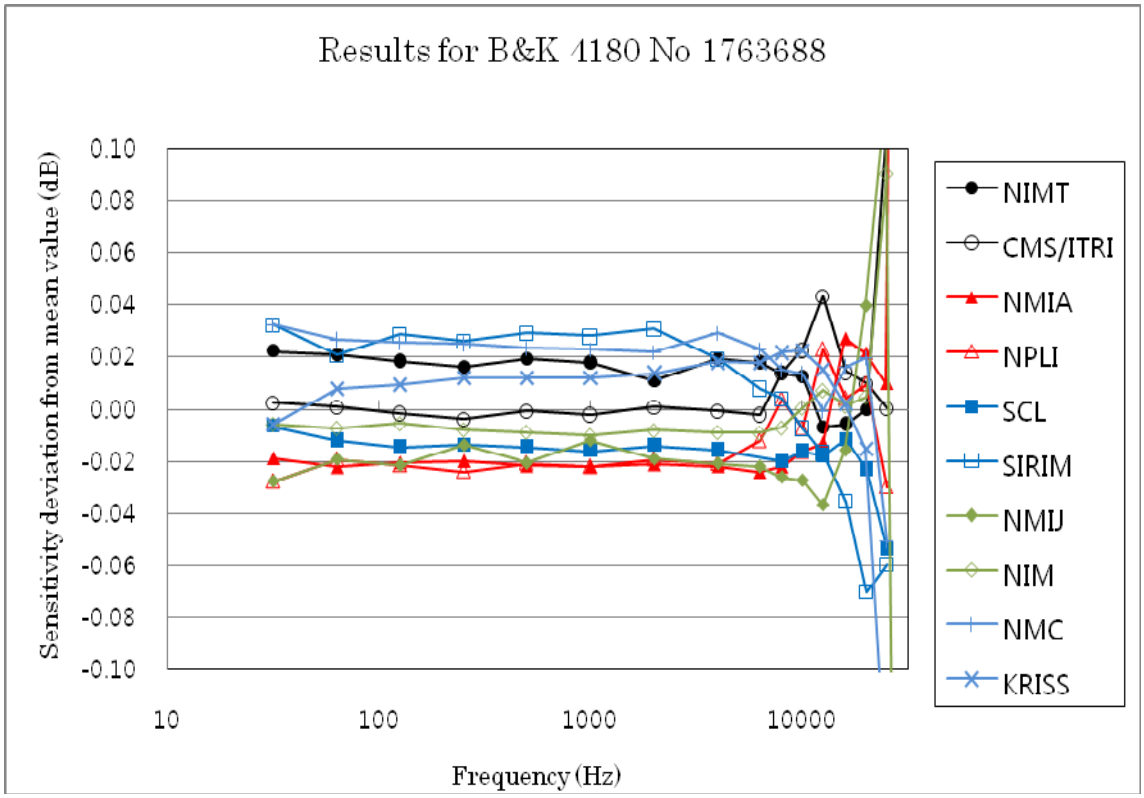


Fig. 3 (a). Sensitivity deviations from the mean value for B&K4180 No 1763688.

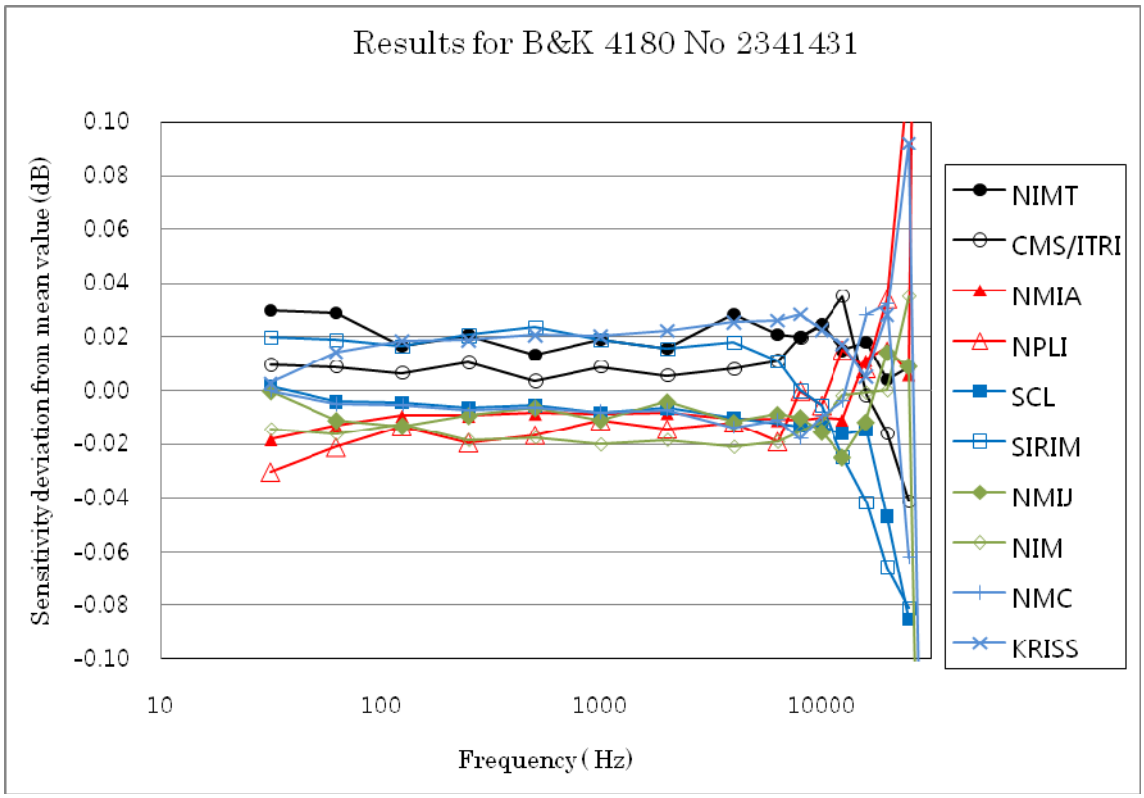


Fig. 3 (b). Sensitivity deviations from the mean value for B&K4180 No 2341431.

Table 7 (a). Sensitivity deviations from the mean value for B&K4180 No 1763688 (dB).

Freq. /Hz	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	0.02	0.00	-0.02	-0.03	-0.01	0.03	-0.03	-0.01	0.03	-0.01
63	0.02	0.00	-0.02	-0.02	-0.01	0.02	-0.02	-0.01	0.03	0.01
125	0.02	0.00	-0.02	-0.02	-0.01	0.03	-0.02	-0.01	0.03	0.01
250	0.02	0.00	-0.02	-0.02	-0.01	0.03	-0.01	-0.01	0.03	0.01
500	0.02	0.00	-0.02	-0.02	-0.01	0.03	-0.02	-0.01	0.02	0.01
1000	0.02	0.00	-0.02	-0.02	-0.02	0.03	-0.01	-0.01	0.02	0.01
2000	0.01	0.00	-0.02	-0.02	-0.01	0.03	-0.02	-0.01	0.02	0.01
4000	0.02	0.00	-0.02	-0.02	-0.02	0.02	-0.02	-0.01	0.03	0.02
6300	0.02	0.00	-0.02	-0.01	–	0.01	-0.02	-0.01	0.02	0.02
8000	0.01	0.01	-0.02	0.00	-0.02	0.00	-0.03	-0.01	0.02	0.02
10000	0.01	0.02	-0.02	-0.01	-0.02	-0.01	-0.03	0.00	0.01	0.02
12500	-0.01	0.04	-0.01	0.02	-0.02	-0.02	-0.04	0.01	0.00	0.02
16000	-0.01	0.01	0.03	0.00	-0.01	-0.04	-0.02	0.00	0.02	0.00
20000	0.00	0.01	0.02	0.01	-0.02	-0.07	0.04	0.01	0.02	-0.01
25000	0.11	0.00	0.01	-0.03	-0.05	-0.06	0.12	0.09	-0.05	-0.14
31500	–	–	0.90	–	–	–	-0.76	–	–	-0.14

Table 7 (b). Sensitivity deviations from the mean value for B&K4180 No 2341431 (dB).

Freq. /Hz	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	0.03	0.01	-0.02	-0.03	0.00	0.02	0.00	-0.01	0.00	0.00
63	0.03	0.01	-0.01	-0.02	0.00	0.02	-0.01	-0.02	-0.01	0.01
125	0.02	0.01	-0.01	-0.01	0.00	0.02	-0.01	-0.01	-0.01	0.02
250	0.02	0.01	-0.01	-0.02	-0.01	0.02	-0.01	-0.02	-0.01	0.02
500	0.01	0.00	-0.01	-0.02	-0.01	0.02	-0.01	-0.02	-0.01	0.02
1000	0.02	0.01	-0.01	-0.01	-0.01	0.02	-0.01	-0.02	-0.01	0.02
2000	0.02	0.01	-0.01	-0.01	-0.01	0.02	0.00	-0.02	-0.01	0.02
4000	0.03	0.01	-0.01	-0.01	-0.01	0.02	-0.01	-0.02	-0.01	0.03
6300	0.02	0.01	-0.01	-0.02	–	0.01	-0.01	-0.02	-0.01	0.03
8000	0.02	0.02	-0.01	0.00	-0.01	0.00	-0.01	-0.02	-0.02	0.03
10000	0.02	0.02	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	0.02
12500	0.02	0.04	-0.01	0.02	-0.02	-0.02	-0.02	0.00	0.00	0.02
16000	0.02	0.00	0.01	0.01	-0.01	-0.04	-0.01	0.00	0.03	0.01
20000	0.00	-0.02	0.02	0.03	-0.05	-0.07	0.01	0.00	0.03	0.03
25000	0.01	-0.04	0.01	0.12	-0.09	-0.08	0.01	0.03	-0.06	0.09
31500	–	–	0.74	–	–	–	-0.39	–	–	-0.35

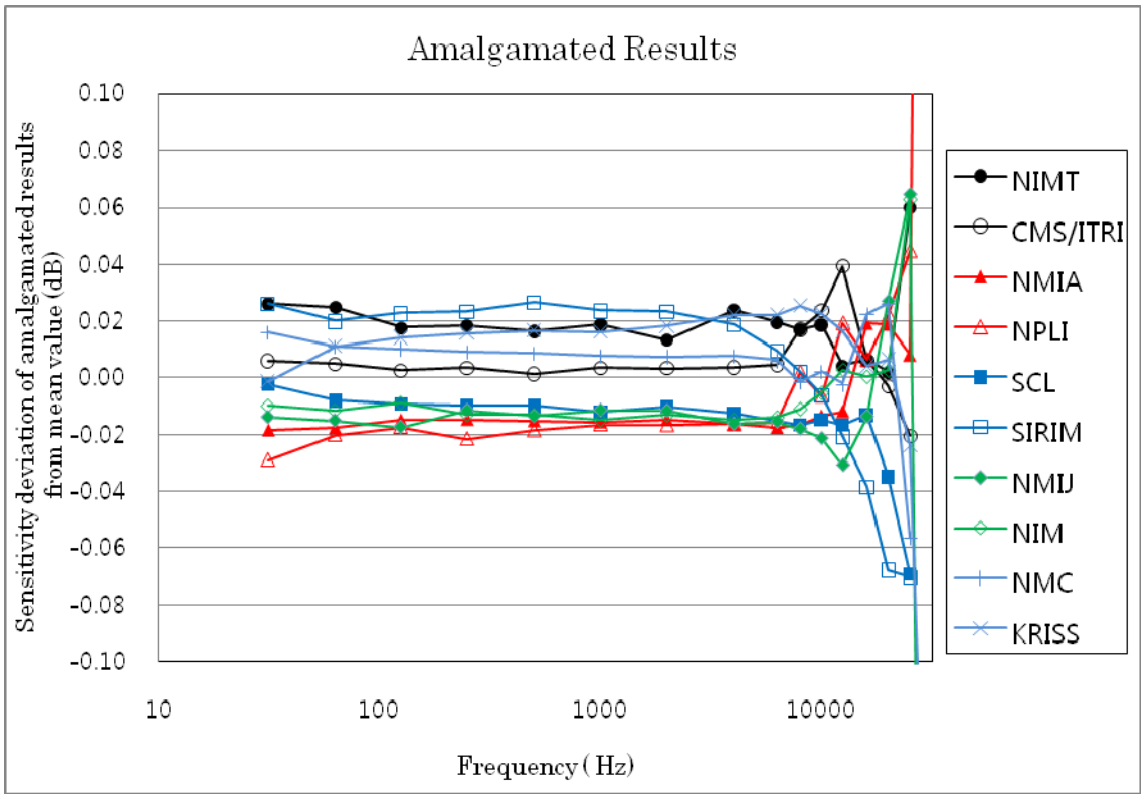


Fig. 4. Deviations in amalgamated results from the mean value.

Table 8. Deviations in amalgamated results from the mean value /dB.

Freq. /Hz	NIMT	CMS/ ITRI	NMIA	NPLI	SCL	SIRIM	NMIJ	NIM	NMC	KRISS
31.5	0.03	0.01	-0.02	-0.03	0.00	0.03	-0.01	-0.01	0.02	0.00
63	0.02	0.00	-0.02	-0.02	-0.01	0.02	-0.02	-0.01	0.01	0.01
125	0.02	0.00	-0.01	-0.02	-0.01	0.02	-0.02	-0.01	0.01	0.01
250	0.02	0.00	-0.01	-0.02	-0.01	0.02	-0.01	-0.01	0.01	0.02
500	0.02	0.00	-0.01	-0.02	-0.01	0.03	-0.01	-0.01	0.01	0.02
1000	0.02	0.00	-0.02	-0.02	-0.01	0.02	-0.01	-0.01	0.01	0.02
2000	0.01	0.00	-0.01	-0.02	-0.01	0.02	-0.01	-0.01	0.01	0.02
4000	0.02	0.00	-0.02	-0.02	-0.01	0.02	-0.02	-0.01	0.01	0.02
6300	0.02	0.00	-0.02	-0.02	–	0.01	-0.02	-0.01	0.01	0.02
8000	0.02	0.02	-0.02	0.00	-0.02	0.00	-0.02	-0.01	0.00	0.03
10000	0.02	0.02	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	0.00	0.02
12500	0.00	0.04	-0.01	0.02	-0.02	-0.02	-0.03	0.00	0.00	0.02
16000	0.01	0.01	0.02	0.01	-0.01	-0.04	-0.01	0.00	0.02	0.00
20000	0.00	0.00	0.02	0.02	-0.03	-0.07	0.03	0.00	0.03	0.01
25000	0.06	-0.02	0.01	0.04	-0.07	-0.07	0.06	0.06	-0.06	-0.02
31500	–	–	0.82	–	–	–	-0.58	–	–	-0.24

6. Linking model for the CCAUV.A–K3

The goal is to establish a linkage between the results of the APMP.AUV.A–K3 and those of the CCAUV.A–K3. Four laboratories (NMIJ, KRISS, NIM and NMIA) listed in table 9 participated in both key-comparisons and play the important role as the linking laboratories.

In December 2002, the protocol for the CCAUV.A–K3 was issued containing the procedures to circulate the standards and a general framework for the measurements. The comparison consisted of two circulations (A and B) with two different standards per circulation.

Participant	Acronym	Country	Circulation
National Metrology Institute of Japan	NMIJ	Japan	A
Korea Research Institute of Science and Standards	KRISS	Korea	A
National Institute of Metrology	NIM	China	B
National Measurement Institute (Australia)	NMIA	Australia	B

Table 9. Participants in both key comparisons for linkage.

It is planned to link the APMP.AUV.A–K3 results with the CCAUV.A–K3 results using the results from the four laboratories that also participated in the CCAUV.A–K3 comparison. The methodology described in the CCAUV.A–K3 comparison will be used for the linkage and to determine the degrees of equivalence. The results of the linking will be included in a further report.

7. Conclusion

The KRISS has piloted the regional key comparison APMP.AUV.A–K3 and reported the results. Deviations from the mean value for all participants are within their declared expanded uncertainties for all frequencies except the optional 31.5 kHz. The results from the participants will be linked to the key comparison reference values of the CIPM key comparison CCAUV.A–K3.

Acknowledgement

The authors gratefully acknowledge all the participating institutes for their thorough cooperation and fruitful discussion.

References

[1] Cutanda Henríquez V., Rasmussen K., Final report on the key comparison CCAUV.A-K3, *Metrologia* **43** (2006) *Tech. Suppl.* 09001.

[2] Rasmussen K., The static pressure and temperature coefficients of laboratory standard microphones, *Metrologia* **36** (1999) 265–273.

Appendix A. Uncertainty budgets

The uncertainty budgets submitted by the participants are reproduced here.

NIMT

National Institute of Metrology (Thailand)

Uncertainty Components of the Pressure Sensitivity Level for LS2P Microphone (unit quote in dB)

Frequency /Hz	31.5	63	125	250	500	1 k	2k	4k	6.3k	8k	10k	12.5k	16k	20k	25k
$U_{Pol.V}$	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
$U_{PCorr.}$	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0046	0.0073	0.0187	0.0200
$U_{Tcorr.}$	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0013	0.0032	0.0100
$U_{RH.Corr.}$	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
$U_{HWcf.}$	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
U_P	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
$U_{Spec.H}$	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
$U_{Cap.}$	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
$U_{Elect.Para.}$	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073
$U_{Coupler}$	0.0176	0.0053	0.0032	0.0031	0.0031	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030
$U_{mic.}$	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0100	0.0300	0.0500
$U_{A\ Repeat}$	0.0120	0.0040	0.0030	0.0030	0.0030	0.0040	0.0030	0.0020	0.0020	0.0030	0.0040	0.0060	0.0100	0.0110	0.0400
Combined Standard Uncertainty	0.0268	0.0176	0.0169	0.0169	0.0169	0.0170	0.0168	0.0167	0.0167	0.0168	0.0170	0.0176	0.0214	0.0398	0.0693
Expanded Uncertainty (k = 2)	0.0536	0.0352	0.0337	0.0337	0.0337	0.0341	0.0337	0.0334	0.0334	0.0337	0.0341	0.0353	0.0429	0.0796	0.1386
Reported uncertainty /dB	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.08	0.14

Uncertainty Budget For LS2P Microphone (dB)

Symbol	Freq. / Source of uncertainty, x_i	31.5	63	125	250	500	1000	2000	4000	6300	8000	10000	12500	16000	20000	25000
$Cor_{R,,n}$																
$u_{meas,deviation}$	Voltage ratio correction	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
$u_{meas,specification}$	Voltage Ratio, accuracy	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
Cor_{CV}																
$V_{coup,specification}$	Coupler volume correction	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Cor_{Ps}																
$P_{s,deviation}$	Static pressure correction	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
Cor_C																
$C_{traceability}$	Capacitance correction	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
$S_{ref.}$																
Cor_{HW}	Heat conduction correction	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
k	Ratio of specific heats	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
$P_{s,error}$	Static pressure	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
T_{error}	Ambient temperature	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.014	0.004	0.008	0.018
H_{errot}	Ambient humidity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.001	0.003
$L_{F,error}$	Microphone Cavity depth	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.005	0.008	0.018	0.011	0.019	0.043
$M_{P,repeat}$	Repeatability	0.003	0.005	0.005	0.005	0.006	0.006	0.006	0.005	0.005	0.005	0.008	0.013	0.019	0.016	0.026
u_c	Combined standard uncertainty	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.04	0.06
U	Expanded uncertainty ($k = 2$)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.08	0.06	0.08	0.12
Stated Uncertainty		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.08	0.08	0.08	0.12

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Uncertainty Estimates — APMP-K3 Key Comparison on LS2P Microphones — NMI Australia — Jun-06 — Meldrum/Bell/Narang

	Component	Symbol		Unit	Source	31.5	63	125	250	500	1000	2000	4000	6300	8000	10000	12500	16000	20000	25000	31500	R	Dof	Distrib'n
						31.5	63	125	250	500	1k	2k	4k	6.3k	8k	10k	12.5k	16k	20k	25k	31.5k			
	Electrical measurements					**0.004**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**	**0.00426**			
					u^4	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**	**3.3E-10**		**93**	
1.1	Series Z	C	0.001	nF	NMI	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019		30	Rect
1.2	Voltage ratio	Vr		V	NMI	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027		30	Rect
1.3	Frequency	f		Hz	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		30	Rect
1.4	Inherent Noise			V	NMI	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		9	Normal
1.5	Distortion	D		ratio	B&K	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		30	Rect
1.6	Cross talk			ratio	B&K	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025		30	Rect
1.7	Polarising V	Pv		V	NMI	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010		30	Rect
	Coupler properties					**0.010**	**0.00711**	**0.00613**	**0.00515**	**0.00125**	**0.00125**	**0.00125**	**0.00128**	**0.0012**	**0.00113**	**0.00106**	**0.00103**	**0.00117**	**0.0017**	**0.00298**	**0.00775**			
					u^4	**1.03E-08**	**2.6E-09**	**1.4E-09**	**7.1E-10**	**2.4E-12**	**2.4E-12**	**2.4E-12**	**2.7E-12**	**2.1E-12**	**1.6E-12**	**1.3E-12**	**1.1E-12**	**1.8E-12**	**8.4E-12**	**7.9E-11**	**3.6E-09**		**13**	
2.1	Length	Cl	0.007	mm	NMI	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0009	0.0008	0.0007	0.0005	0.0006	0.0011	0.0023	0.0067		30	Normal
2.2	Diameter	Cd	0.004	mm	NMI	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008	0.0008	0.0009	0.0010	0.0013	0.0019	0.0039		30	Normal
2.3	Volume	Cv	1.E-06	mm^3	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		30	Normal
2.4	Surface Area	CA	1.E-06	mm^2	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		30	Normal
2.5	Air Leakage					0.010	0.007	0.006	0.005	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	12.5	
	Microphone parameters					**0.014**	**0.01423**	**0.01419**	**0.01416**	**0.01415**	**0.01415**	**0.01414**	**0.01415**	**0.01349**	**0.0123**	**0.01137**	**0.01069**	**0.01018**	**0.01128**	**0.02316**	**0.06613**			
					u^4	**4.2E-08**	**4.1E-08**	**4E-08**	**4E-08**	**4E-08**	**4E-08**	**4E-08**	**4E-08**	**3.3E-08**	**2.3E-08**	**1.7E-08**	**1.3E-08**	**1.1E-08**	**1.6E-08**	**2.9E-07**	**1.9E-05**		**63**	
3.1	Front depth	Fd	0.01	mm	NMI	0.0022	0.0016	0.0011	0.0008	0.0006	0.0004	0.0002	0.0001	0.0002	0.0004	0.0008	0.0012	0.0018	0.0025	0.0042	0.0198		30	Normal
3.2	Front volume	Fv	0.5	mm^3	NMI	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100		30	Normal
3.3	Equiv volume	Ve	0.5	mm^3	NMI	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0090	0.0070	0.0050	0.0030	0.0002	0.0004	0.0130	0.0560		30	Normal
3.4	Resonance freq	Fr	200	Hz	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0001	0.0001	0.0001	0.0001	0.0000	0.0005	0.0022	0.0050	0.0148		30	Normal
3.5	Loss factor	Loss	0.02	ratio	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0001	0.0004	0.0010	0.0015	0.0019	0.0019	0.0001	0.0040	0.0150	0.0230		30	Rect
	Ambient Conditions					**0.011**	**0.0022**	**0.00219**	**0.00219**	**0.00214**	**0.00213**	**0.00219**	**0.00219**	**0.00226**	**0.00238**	**0.00245**	**0.00259**	**0.00259**	**0.00613**	**0.00305**	**0.00733**			
					u^4	**1.66E-08**	**2.3E-11**	**2.3E-11**	**2.3E-11**	**2.1E-11**	**2.1E-11**	**2.3E-11**	**2.3E-11**	**2.6E-11**	**3.2E-11**	**3.6E-11**	**4.5E-11**	**4.5E-11**	**1.4E-09**	**8.7E-11**	**2.9E-09**		**59.8**	
4.1	Static pressure	Pamb	0.03	kPa	NMI	0.0013	0.0013	0.0013	0.0013	0.0012	0.0012	0.0013	0.0013	0.0014	0.0015	0.0016	0.0018	0.0018	0.0014	0.0014	0.0010		30	Triangular
4.2	Drift in pressure	Pdrift	0.01	kPa	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		30	Rect
4.3	Pcoeft unknown	Pcoeft		dB/kPa	NMI	0.0086	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0029	0.0017	0.0002		30	Rect
4.4	Mic temperature	Tmic	0.3	°C	NMI	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0003	0.0001	0.0001		30	Normal
4.5	Tcoeft unknown	Tcoeft		dB/°C	NMI	0.0072	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0051	0.0006	0.0019		30	Rect
4.6	Relative Humidity	%RH	3	%	NMI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0005	0.0005	0.0005	0.0005	0.0010	0.0020	0.0070		30	Normal
	Physical Corrections					**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.004**	**0.005**	**0.007**	**0.011**	**0.016**	**0.023**	**0.031**	**0.043**	**0.062**			
					u^4	**1.34E-10**	**1.3E-10**	**1.3E-10**	**1.3E-10**	**1.3E-10**	**1.3E-10**	**1.3E-10**	**3.4E-10**	**8E-10**	**3.1E-09**	**1.3E-08**	**6.8E-08**	**2.8E-07**	**9.1E-07**	**3.4E-06**	**1.4E-05**		**19.1**	
5.1	Radial wave motion Corr.			dB	KR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0010	0.0020	0.0030	0.0050	0.0100	0.0150	0.0200	0.0300	20	12.5	Normal
5.2	Viscosity of air			dB	KR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0002	0.0005	0.0010	0.0030	0.0050	0.0100	0.0150	0.0200	20	12.5	Normal
5.3	Air properties			dB	KR	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0015	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013	0.0012	20	12.5	Normal
5.4	Correction to ref conditions			dB	KR	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0040	0.0050	0.0070	0.0100	0.0150	0.0200	0.0250	0.0350	0.0500	20	12.5	Normal
	Rounding and Type A					**0.030**	**0.025**	**0.020**	**0.015**	**0.012**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.015**	**0.020**	**0.030**	**0.040**	**0.050**	**0.064**			
					u^4	**8.1E-07**	**4E-07**	**1.7E-07**	**5.4E-08**	**2.3E-08**	**1.2E-08**	**1.2E-08**	**1.2E-08**	**1.2E-08**	**1.2E-08**	**5.4E-08**	**1.7E-07**	**8.3E-07**	**2.6E-06**	**6.3E-06**	**1.7E-05**		**12.5**	
6.1	Rounding		0.0005		NMI	0.0003	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029		30	Rect
6.2	Type A			dB	Data	0.0300	0.0250	0.0200	0.0150	0.0120	0.0100	0.0100	0.0100	0.0100	0.0100	0.0150	0.0200	0.0300	0.0400	0.0500	0.0640	20	12.5	Normal
	Combined Uncertainty, uc					0.037	0.030	0.026	0.022	0.020	0.019	0.019	0.019	0.019	0.018	0.022	0.028	0.040	0.052	0.070	0.111			
	Effective dof					28.0	25.7	32.9	48.4	60.2	74.7	74.8	77.4	78.0	78.8	47.3	38.3	30.3	29.6	35.4	63.9			
	k factor					2.05	2.06	2.04	2.01	2.00	1.99	1.99	1.99	1.99	1.99	2.01	2.03	2.04	2.05	2.03	2.00			
	Expanded Uncertainty, U95 for k=2					**0.074**	**0.061**	**0.052**	**0.045**	**0.039**	**0.037**	**0.037**	**0.038**	**0.037**	**0.037**	**0.045**	**0.057**	**0.079**	**0.105**	**0.140**	**0.223**			
	U95 rounded to 2 dP					**0.07**	**0.06**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.06**	**0.08**	**0.10**	**0.14**	**0.22**			
	Stated Uncertainty					**0.08**	**0.06**	**0.05**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.05**	**0.06**	**0.08**	**0.1**	**0.15**	**0.25**			

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	Uncertainty of 4180	Microphones													
S.No.	Sources of Uncertainity	Probability Distributio	Sensitivity		Uncertainity Contribution										
		Type - A or B	Coefficient	20 Hz	31.5 Hz	63 Hz	125 Hz	250 Hz	1KHz	4 KHz	8 KHz	10 KHz	12.5 kHz	16 kHz	20 kHz	25 kHz	
1	Static Pressure	Type-B, Rectangular	1	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0017	0.0017	0.0017	0.0017	
2	Temperature	Type-B, Rectangular	1	0.0004	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0013	0.0022	0.004	0.0072	0.0112	0.024	
3	Relative Humidity	Type-B, Rectangular	1	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0006	0.0008	0.0012	0.002	0.004	
4	Coupler Volume	Type-B, Normal	1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
5	Equivalent & Front Volume	Type-B, Normal	1	0.0067	0.0068	0.0069	0.007	0.007	0.007	0.0068	0.0058	0.0049	0.0035	0.0014	0.0013	0.0075	
6	Microphone Front Length	Type-B, Normal	1	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0004	0.0016	0.0026	0.0045	0.0075	0.012	0.028	
7	Series capacitance	Type-B, Rectangular	1	0.0065	0.0048	0.0028	0.0024	0.0018	0.0018	0.0024	0.0027	0.0028	0.0032	0.0035	0.0038	0.005	
8	Voltage Ratio (DVM)	Type-B, Rectangular	1	0.015	0.015	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.015	0.015	0.015	
9	Voltage Ratio(Cr.talk)	Type-B, Rectangular	1	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	
10	Voltage Ratio (Noise)	Type-B, Rectangular	1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
11	Voltage Ratio(Distortion)	Type-B, Rectangular	1	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
12	Polarization Voltage	Type-B, Normal	1	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	
13	Electrical Parameters																
	incl. Transfer impedance,acc.of voltmeter	Type-B, Rectangular	1	0.05	0.05	0.05	0.02	0.02	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	
14	Specific Heat Ratio	Type-B, Normal	1	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	
15	Wave motion correction	Type-B, Rectangular	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
16	Heat Conduction correction	Type-B, Rectangular	1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
17	Reproducibility	Type-A, Normal		0.005	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.005	0.005	0.015	0.045	
	Uncertainity of Sensitivity at Meas. conditions																
	Sensitivity Correction for Static pressure	Type-B, Rectangular	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0008	0.0022	0.0024	0.0014	0.008	0.0175	0.014	
	Sensitivity Correction for Temperature	Type-B, Rectangular	1	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.003	0.0033	0.0032	0.0031	0.0065	0.0068	
	Uncertainity of Sensitivity at ref. Cond.			0.058067	0.057912	0.054	0.04	0.025	0.025	0.039	0.05	0.054	0.053	0.058945	0.06415	0.083526	
	Expanded Uncertainity dB			***0.12***	***0.12***	***0.11***	***0.08***	***0.05***	***0.05***	***0.08***	***0.1***	***0.11***	***0.11***	***0.12***	***0.13***	***0.17***	**dB**

Uncertainty Budget for LS2P Microphones

Uncertainty Components	Standard uncertainty in 0.001 dB													
	31.5 Hz	63.0 Hz	125.0 Hz	250.0 Hz	500.0 Hz	1.0 kHz	2.0 kHz	4.0 kHz	8.0 kHz	10.0 kHz	12.5 kHz	16.0 kHz	20.0 kHz	25.0 kHz
Electrical Measurements														
1. Voltage ratios	4	4	4	4	4	4	4	4	4	4	4	4	4	4
2. Polarizing voltage	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3. Frequency	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Capacitance	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Coupler Dimensions														
5. Coupler length	5	5	5	5	5	5	5	5	5	5	5	10	15	50
6. Coupler diameter	2	2	2	2	2	2	2	2	2	2	2	5	10	20
7. Coupler surface area	1	1	1	1	1	1	1	1	1	1	1	2	10	20
Microphone Parameters														
8. Font cavity depth	2	2	2	2	2	2	2	2	2	2	2	2	2	5
9. Front cavity volume	5	5	5	5	5	5	5	5	5	5	5	5	5	10
10. Equivalent volume	5	5	5	5	5	5	5	5	5	5	5	5	5	10
11. Resonant frequency	3	3	3	3	3	3	3	3	3	3	3	10	10	15
12. Loss factor	3	3	3	3	3	3	3	3	3	3	3	10	10	15
Ambient Conditions														
13. Static pressure	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14. Temperature	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15. Pressure coeff.	10	2	2	2	2	2	2	2	2	2	2	5	10	10
16. Temperature coeff.	10	2	2	2	2	2	2	2	2	2	2	5	10	10
Others														
17. Theory imperfection	25	5	2	2	2	2	2	2	2	2	2	5	10	10
18. Repeatability	20	10	10	10	10	10	10	10	10	10	10	10	20	20
Combined standard uncert.	37.1	16.9	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	24.7	37.8	68.7
Coverage factor	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Expanded combined uncert.	74.2	33.8	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	49.3	75.6	137.5
Stated Uncertainty	80	40	40	40	40	40	40	40	40	40	40	50	80	140

Uncertainty for LS2P Microphones - NML, SIRIM Berhad, MALAYSIA for Regional Key Comparison APMP.AUV.A-K3

No	Input Parameter	Std U	Unit	31.5	63	125	250	500	1000	2000	4000	6300	8000	10000	12500	16000	20000	25000
2.1.1	Static Pressure	0.039	kPa	0.0007	0.0005	0.0004	0.0003	0.0002	0.0002	0.0003	0.0008	0.0020	0.0033	0.0053	0.0086	0.0151	0.0268	0.0594
2.1.2	Temperature	3.057	K	0.0015	0.0009	0.0007	0.0005	0.0004	0.0003	0.0005	0.0016	0.0037	0.0060	0.0096	0.0157	0.0277	0.0492	0.1093
2.1.3	Relative Humidity	6.066	%	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0005	0.0007	0.0008	0.0012	0.0018	0.0029	0.0060
	Amb. Conditions			0.0017	0.0011	0.0009	0.0006	0.0005	0.0005	0.0007	0.0018	0.0043	0.0069	0.0110	0.0179	0.0316	0.0561	0.1246
2.2.1	Coupler Length	0.00101	mm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0003	0.0006	0.0010	0.0017	0.0038
2.2.2	Coupler Diameter	0.00473	mm	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
2.2.3	Coupler Volume	0.35063	mm^3	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0039	0.0039	0.0039	0.0036
2.2.4	Coup. Surf. Area	0.2796	mm^2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	Coupler			0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0039	0.0040	0.0043	0.0052
2.3.1	Mic. Front Length	0.01	mm	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001	0.0003	0.0010	0.0025	0.0040	0.0065	0.0106	0.0187	0.0331	0.0734
2.3.2	Front Vol	0.6	mm^3	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0130	0.0130	0.0131	0.0133	0.0135	0.0135	0.0125
2.3.3	Eqv. Vol	1	mm^3	0.0202	0.0206	0.0208	0.0210	0.0211	0.0211	0.0210	0.0200	0.0180	0.0157	0.0122	0.0067	0.0010	0.0011	0.0292
2.3.4	Diaphragm Res.	1300	Hz	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0005	0.0010	0.0019	0.0025	0.0040	0.0271	0.0490
2.3.5	Diaph. Damp. Fac.	0.1	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0013	0.0030	0.0044	0.0054	0.0048	0.0027	0.0058	0.0425
	Microphones			0.0240	0.0243	0.0245	0.0246	0.0247	0.0248	0.0246	0.0239	0.0225	0.0213	0.0199	0.0190	0.0236	0.0453	0.1030
2.4.1	Series Cap.	see table	pF	0.0014	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0010	0.0010
2.4.2	Volt. Ratio, DVM	see table	-	0.0094	0.0094	0.0093	0.0093	0.0093	0.0093	0.0094	0.0094	0.0094	0.0094	0.0105	0.0105	0.0105	0.0105	0.0105
2.4.3	Volt. Ratio, Cr-talk	< -66 dB	-	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
2.4.4	Volt. Ratio, Noise	< -46 dB	-	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
2.4.5	Volt. Ratio, Distort.	< -46 dB	-	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
2.4.6	Frequency	12	ppm	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004
2.4.7	Pol. Voltage	0.023	V	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
	Electrical Parameters			0.0099	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0098	0.0109	0.0109	0.0109	0.0109	0.0109
2.5	Repeatibility		dB	0.0097	0.0100	0.0101	0.0101	0.0099	0.0097	0.0092	0.0078	0.0055	0.0062	0.0103	0.0156	0.0155	0.0223	0.0162
2.6	Result Rounding	< 0.005	dB	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058
	Uncertainty at Measurement Conditions		dB	0.0286	0.0289	0.0291	0.0292	0.0292	0.0292	0.0289	0.0279	0.0264	0.0261	0.0281	0.0331	0.0443	0.0766	0.1630
2.7	Sensitivity Correction for Static Pressure		dB	0.0011	0.0011	0.0011	0.0012	0.0013	0.0013	0.0012	0.0005	0.0010	0.0028	0.0059	0.0086	0.0033	0.0187	0.0150
2.7	Sensitivity Correction for Temperature		dB	0.0010	0.0010	0.0010	0.0010	0.0010	0.0011	0.0018	0.0035	0.0066	0.0101	0.0166	0.0250	0.0289	0.0269	0.0281
	Sens Corr to Reference Enviromental Cond.		dB	0.0015	0.0015	0.0015	0.0016	0.0016	0.0017	0.0022	0.0035	0.0067	0.0105	0.0176	0.0264	0.0291	0.0328	0.0319
	Expanded Uncertainty (k=2)		dB	0.0286	0.0289	0.0291	0.0292	0.0293	0.0292	0.0290	0.0281	0.0273	0.0282	0.0332	0.0423	0.0530	0.0833	0.1661
	Reported Uncertainty		dB	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.05**	**0.06**	**0.07**	**0.10**	**0.17**

Uncertainty Budget for APMP.AUV.A-K3 (NMIJ/AIST)

Uncertainty components			sensitivity coefficient	31.5	63	125	250	500	1000	2000	4000	6300	8000	10000	12500	16000	20000	25000	31500
static pressure	A	normal	0.5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
specific heat ratio	A	normal	0.5	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
coupler volume (including front cavity volumes)	A	normal	0.5	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
equivalent volumes	A	normal	0.5	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
voltage transfer function between input terminal of transmitter and output terminal of receiver		combined	0.866	0.010	0.010	0.010	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.005	0.004	0.004	0.060	0.060	0.060
cross-talk	B	rectangular		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
distortion (linearlity of FFT analyzer)	B	rectangular		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
attenuator	B	rectangular		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
transmitter and receiver ground shield	A	normal		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
repeatability	A	normal		0.009	0.009	0.009	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.004	0.003	0.003	0.060	0.060	0.060
leakage of sound	A	normal		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
electrical impedance of transmitter		combined	0.5	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
distortion (linearlity of FFT analyzer)	B	rectangular		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
repeatability	A	normal		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
polarizing voltage	A	normal	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
rounding error	B	rectangular	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
static pressure coefficient of pressure sensitivity	A	normal	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.003	0.001
temperature coefficient of pressure sensitivity	A	normal	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.000
coupler correction(heat conduction, capillary tube and wave motion)		combined	1	0.008	0.006	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.010	0.017	0.031	0.068	0.324
static pressure, temperature and relative humidity	A	normal		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.006	0.026
coupler length and diameter	A	normal		0.006	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.006	0.010	0.017	0.030	0.067	0.303
capillary tube length and diameter	A	normal		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
resonance frequency, quality factor and tension of microphone diaphragm	A	normal		0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.005	0.005	0.004	0.004	0.002	0.001	0.008	0.012	0.111
Combined standard uncertainty of pressure sensitivity				0.016	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.016	0.021	0.062	0.087	0.328
Expanded uncertainty of pressure sensitivity (coverage factor k =2)				0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.13	0.18	0.66
Stated uncertainty				0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.13	0.18	0.66

Table: uncertainty budget of LS2aP

No.	resource	symbol	20Hz	31.5Hz	50Hz	63Hz	125Hz	250Hz	1kHz	2kHz	4kHz	8kHz	10kHz	12.5kHz	16kHz	20kHZ	25kHz
1	Sensitive calibration	$v_1=S_1$	0.0118	0.0101	0.0100	0.0077	0.0093	0.0086	0.0085	0.0085	0.0089	0.0113	0.0133	0.0159	0.0194	0.0219	0.0271
2	Polarization volt.	v_2	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004
3	Volt. Ratio	v_3	0.0009	0.0009	0.0007	0.0007	0.0004	0.0004	0.0004	0.0004	0.0007	0.0007	0.0007	0.0024	0.0024	0.0024	0.0024
4	Cross talk	v_3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
5	Noise	v_5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
6	Distortion	v_6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
7	Frequency	v_7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	Length of coupler	v_8	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0006	0.0010	0.0016	0.0026	0.0046	0.0100
9	Diameter of coupler	v_9	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	Surface area of coupler	v_{10}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	Volume of coupler	v_{11}	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037
12	Leak of coupler	v_{12}	0.0217	0.0087	0.0050	0.0022	0.0011	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	Length of front cavity of microphone	v_{13}	0.0002	0.0002	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0004	0.0016	0.0026	0.0045	0.0075	0.0100	0.0140
14	Affix front cavity	v_{14}	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

NMC uncertainty budget for LS2P microphone - Key Comparison APMP.AUV.A-K3

	31.2 Hz	63 Hz	125 Hz	250 Hz	1 kHz	4 kHz	8 kHz	10 kHz	12.5kHz	16 kHz	20 kHz	25 kHz
Ambient												
Static Pressure Correction	0.0010	0.0010	0.0010	0.0010	0.0010	0.0008	0.0005	0.0018	0.0027	0.0011	0.0081	0.0184
Temperature Correction	0.0015	0.0015	0.0015	0.0015	0.0015	0.0026	0.0062	0.0087	0.0124	0.0160	0.0108	0.0104
	0.0018	0.0018	0.0018	0.0018	0.0018	0.0027	0.0062	0.0089	0.0127	0.0160	0.0135	0.0211
Plane Wave Coupler:												
Length	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	0.0006	0.0010	0.0016	0.0026	0.0046	0.0100
Diameter	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Volume	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0037	0.0038	0.0038	0.0037
Surface Area	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coupler Leakage	0.0173	0.0044	0.0011	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0177	0.0057	0.0039	0.0037	0.0037	0.0037	0.0037	0.0038	0.0040	0.0046	0.0060	0.0107
½" Microphone Type 4180												
Mic Front Length	0.0003	0.0002	0.0002	0.0000	0.0000	0.0006	0.0024	0.0039	0.0068	0.0113	0.0180	0.0420
Equ. & Front Vol.	0.0068	0.0069	0.0070	0.0070	0.0070	0.0068	0.0058	0.0049	0.0035	0.0014	0.0013	0.0075
Diaphragm Res.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0010	0.0022	0.0026	0.0060	0.0280	0.0580
Diaph. Damp. Fac.	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0040	0.0052	0.0044	0.0040	0.0070	0.0300
	0.0068	0.0069	0.0070	0.0070	0.0070	0.0068	0.0075	0.0084	0.0092	0.0135	0.0340	0.0780
Series Capacitance	0.0015	0.0012	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0011
Voltage Ratio												
DVM	0.0015	0.0012	0.0008	0.0008	0.0008	0.0012	0.0012	0.0012	0.0042	0.0042	0.0042	0.0042
Cross-talk	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Noise	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Distortion	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Frequency	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003
Polarisation Voltage	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036
	0.0046	0.0045	0.0044	0.0044	0.0044	0.0045	0.0045	0.0045	0.0061	0.0061	0.0061	0.0061
Reproducibility	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0080	0.0147	0.0200	0.0347
Result Rounding	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058	0.00058
Combine (Type B)	0.021	0.013	0.012	0.012	0.012	0.012	0.014	0.016	0.019	0.027	0.043	0.089
Refmic uncertainty 95%	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.07	0.12
Combine with Type B (1s)	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.07
Type A (STDEV 200ppm)	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225	0.01225
Combine Type A+ B (1s)	0.02980	0.02043	0.02032	0.02032	0.02032	0.02033	0.02059	0.02092	0.02532	0.03088	0.04276	0.07564
DOF (n=55)	1.59E+03	4.26E+02	4.17E+02	4.17E+02	4.16E+02	4.18E+02	4.39E+02	4.69E+02	1.00E+03	2.22E+03	8.17E+03	8.00E+04
k at 95%	2.01	2.02	2.02	2.02	2.02	2.02	2.02	2.01	2.01	2.01	2.01	2.01
Expanded Uncertainty	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.09	0.16

KRISS: Uncertainty Budget for LS2P

MEASURED QUANTITY	Symbol	Unc.	Unit	31,5	63	125	250	500	1000	2000	3150	4000	5000	6300	8000	10000	12500	16000	20000	25000	31500
Electrical Transfer Impedance				**0,0112**	**0,0109**	**0,0107**	**0,0067**	**0,0054**	**0,0050**	**0,0055**	**0,0057**	**0,0057**	**0,0057**	**0,0057**	**0,0057**	**0,0053**	**0,0117**	**0,0117**	**0,0117**	**0,0117**	**0,0159**
Series Capacitance	C	Table	nF	0,0102	0,0098	0,0097	0,0048	0,0029	0,0019	0,0029	0,0048	0,0048	0,0048	0,0048	0,0048	0,0048	0,0096	0,0095	0,0095	0,0095	0,0095
Voltage Ratio	VR	Table		0,0031	0,0029	0,0028	0,0028	0,0028	0,0028	0,0029	0,0029	0,0029	0,0029	0,0029	0,0029	0,0057	0,0057	0,0057	0,0057	0,0057	0,0122
Cross-talk				0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035	0,0035
Inherent Noise				0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009	0,0009
Distortion				0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0004	0,0005	0,0005	0,0006	0,0005	0,0004	0,0003	0,0011	0,0000	0,0000	0,0000
Frequency	f		Hz	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Reveiver Ground Shield		B&K		0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003
Transmitter Ground Shield		B&K		0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003
Coupler Properties				**0,0039**	**0,0039**	**0,0039**	**0,0039**	**0,0040**	**0,0039**	**0,0039**	**0,0039**	**0,0039**	**0,0039**	**0,0039**	**0,0039**	**0,0040**	**0,0042**	**0,0050**	**0,0059**	**0,0141**	**0,0553**
Coupler Length	lcoup	0,0020	mm	0,0014	0,0014	0,0014	0,0014	0,0015	0,0014	0,0014	0,0014	0,0014	0,0013	0,0012	0,0011	0,0008	0,0004	0,0003	0,0017	0,0058	0,0345
Coupler Diameter	dcoup	0,0030	mm	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0022	0,0023	0,0023	0,0023	0,0023	0,0022	0,0017
Coupler Volume	Vcoup	0,2470	mm3	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0027	0,0026	0,0026	0,0026	0,0020
Coupler Surface Area	Scoup	0,1440	mm2	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Static Pressure	Ps	0,0275	kPa	0,0012	0,0012	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0011	0,0012	0,0012	0,0012	0,0012	0,0011	0,0008
Temperature	T	0,3464	K	0,0001	0,0001	0,0001	0,0001	0,0000	0,0000	0,0001	0,0001	0,0002	0,0003	0,0004	0,0007	0,0011	0,0018	0,0030	0,0053	0,0119	0,0548
Relative Humidity	RH	3,3164	%	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0003	0,0004	0,0005	0,0006	0,0010	0,0016	0,0033	0,0141
Microphone Parameters				**0,0096**	**0,0097**	**0,0099**	**0,0099**	**0,0100**	**0,0100**	**0,0099**	**0,0098**	**0,0099**	**0,0100**	**0,0105**	**0,0117**	**0,0128**	**0,0121**	**0,0120**	**0,0519**	**0,1353**	**0,8243**
Front Cavity Depth	Lf	0,0030	mm	0,0001	0,0001	0,0001	0,0000	0,0000	0,0000	0,0001	0,0002	0,0003	0,0005	0,0007	0,0012	0,0019	0,0032	0,0054	0,0097	0,0216	0,1006
Front Cavity Volume	Vf	0,2100	mm3	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0045	0,0046	0,0047	0,0047	0,0047	0,0044	0,0035
Equivalent Volume	Veq	0,4200	mm3	0,0085	0,0086	0,0088	0,0088	0,0089	0,0089	0,0088	0,0086	0,0085	0,0081	0,0076	0,0068	0,0053	0,0029	0,0002	0,0004	0,0130	0,0564
Resonance Frequency	fo	2440	Hz	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0001	0,0002	0,0005	0,0010	0,0022	0,0042	0,0065	0,0078	0,0494	0,1018	0,7684
Loss Factor	D	0,1600		0,0000	0,0000	0,0000	0,0000	0,0000	0,0001	0,0005	0,0015	0,0024	0,0037	0,0056	0,0079	0,0097	0,0067	0,0057	0,0118	0,0854	0,2751
Additional Heat Conduction Caused by Front Cavity Thread				0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Polarizing Voltage	Uo	0,0048	V	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003	0,0003
Imperfection of Theory				**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**
Heat Conduction Theory				0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Adding of Excess Volume				0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Radial Wave Motion				0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Processing of Results				**0,0152**	**0,0125**	**0,0117**	**0,0117**	**0,0117**	**0,0117**	**0,0117**	**0,0116**	**0,0116**	**0,0119**	**0,0122**	**0,0129**	**0,0154**	**0,0190**	**0,0221**	**0,0252**	**0,0345**	**0,0417**
Rounding Error		0,0050	dB	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058	0,0058
Repeatability of Measurements			dB	0,0140	0,0110	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0100	0,0110	0,0120	0,0150	0,0180	0,0210	0,0240
Static Pressure Corrections				0,0011	0,0011	0,0011	0,0011	0,0012	0,0012	0,0011	0,0010	0,0009	0,0007	0,0003	0,0006	0,0020	0,0032	0,0004	0,0107	0,0261	0,0306
Temperature Corrections				0,0009	0,0009	0,0009	0,0009	0,0009	0,0010	0,0014	0,0019	0,0023	0,0028	0,0036	0,0056	0,0069	0,0132	0,0152	0,0146	0,0061	0,0132
Sum				**0,0216**	**0,0196**	**0,0191**	**0,0171**	**0,0168**	**0,0166**	**0,0167**	**0,0172**	**0,0173**	**0,0174**	**0,0176**	**0,0190**	**0,0221**	**0,0257**	**0,0282**	**0,0597**	**0,1406**	**0,8282**
Total Uncertainty with Residual Effects				0,0270	0,0245	0,0238	0,0214	0,0209	0,0206	0,0209	0,0215	0,0216	0,0217	0,0223	0,0238	0,0276	0,0322	0,0353	0,0746	0,1760	1,0352
Stated Uncertainty				**0,06**	**0,04**	**0,03**	**0,03**	**0,03**	**0,03**	**0,03**	**0,03**	**0,03**	**0,03**	**0,05**	**0,03**	**0,04**	**0,05**	**0,06**	**0,08**	**0,20**	**1,20**