AFRIMETS.AUV.A-K5
Final Report

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ABSTRACT

The Degrees of Equivalence of the AFRIMETS.AUV.A-K5 Regional Key Comparison are reported here as the Final Report. The scope of the comparison covered the complex pressure sensitivities of two LS1P microphones over the frequency range 2 Hz to 10 kHz in accordance with IEC 61094-2: 2009. Four National Metrology Institutes from two different Regional Metrology Organisations participated in the comparison. Two LS1P microphones were circulated simultaneously to all the participants in a circular configuration. One of the microphones sensitivity shifted and all results associated with this microphone were subsequently excluded from further analysis and linking. The AFRIMETS.AUV.A-K5 comparison results were linked to the CCAUV.A-K5 comparison results via dual participation in the CCAUV.A-K5 and AFRIMETS.AUV.A-K5 comparisons. The Degrees of Equivalence, linked to the CCAUV.A-K5 comparison, were calculated for all participants of this comparison.

Contents

1. Introduction

This is the Final Report of the AFRIMETS.AUV.A-K5 regional Key Comparison (KC) as performed under the auspices of the AFRIMETS Acoustics, Ultrasound and Vibration Technical Committee. The comparison was undertaken in order to address the Regional Metrology Organisations (RMOs) needs for maintaining and establishing measurement equivalence. This is in support of the participating NMIs Calibration Measurement Capabilities (CMC) for sound pressure in air using LS1P microphones by the primary pressure reciprocity calibration method. As such the linked Degrees of Equivalence (DoE) is an important outcome of this report.

The AFRIMETS.AUV.A-K5 comparison mirrored the second CIPM CCAUV KC, CCAUV.A-K5 [1], where the artefacts were Laboratory Standard one inch Pressure (LS1P) microphones, were the open-circuit pressure sensitivities were determined using the pressure reciprocity technique. The CCAUV.A-K5 KC concluded in September 2014. The AFRIMETS.AUV.A-K5 comparison Technical Protocol (TP) [2] stipulated the complex sensitivities to be determined in accordance with IEC 61094-2: 2009 [3].

Four National Metrology Institutes (NMIs) from 2 different RMOs participated in this comparison, i.e. AFRIMETS and EURAMET.

This report contains information relating to all the participants measurement methods, measurement results and the linked DoE for each participating NMI.

2. Technical Protocol

This comparison was only concerned with primary methods of calibration according to IEC 61094-2: 2009 for LS1P microphones. The parameters and frequency ranges are indicated in Table 1. The reported open-circuit pressure sensitivities were required to be corrected for reference environmental conditions. The phase parameter was not mandatory, only modulus in the frequency range 20 Hz to 10 kHz.

The microphones that were circulated, two Brüel & Kjær 4160’s with s/n: 811014 and 2036126, were the same microphones that were used for the EURAMET.AUV.A-K5 comparison [4]. This was possible since the measurement cycle of the AFRIMETS.AUV.A-K5 comparison only commenced after the EURAMET.AUV.A-K5 Draft A report was published. This opens up the possibility of comparing results between the two RMO KCs.

The TP of this comparison was approved by the CCAUV Key Comparison Working Group (KCWG) and was subsequently published on the BIPM Key Comparison Database (KCDB) in accordance with CIPM MRA-D-05 [5].

Table 1. Comparison scope.

Frequency spacing	**Frequency range**	**Parameter**	
		Modulus	**Phase**
1/3 octave	2 Hz to 20 Hz	optional	optional
1/12 octave	20 Hz to 10 kHz	mandatory	optional

Circulation of the comparison artefacts and the comparison measurements were performed from September 2015 to February 2016. The circulation roster is detailed in the TP.

3. Participants

The following NMIs participated in this comparison:

- CMI, Czech Republic
- NMISA, South Africa (pilot) *
- NPL, United Kingdom (co-pilot) *
- VTT MIKES, Finland

Participants who participated in CCAUV.A-K5 are indicated with an asterisk.

4. Methods

Although the IEC 61094-2: 2009 edition was specified as the basis according to which the results were to be obtained, variations are to be expected due to varying factors (which can be due to differences in the instrumentation and software implemented) and different approaches to the implementation of the document standard. Explanations of each participant’s system, method and uncertainty matrixes are reported in Annex B and Annex D respectively.

5. Stability of the microphones

The circulation pattern for this comparison was a circular configuration where both microphones were circulated to all participants at the same time.

The two microphones were periodically measured by the NPL UK for stability during the EURAMET.AUV.A-K5 comparison and before and after the AFRIMETS.AUV.A-K5 comparison. Figures 1 and 2 illustrate the microphones sensitivity change per day.

One microphone’s sensitivity was found to have shifted, 4160 s/n: 811014, and its results were subsequently excluded from further analysis or for performing the linking to CCAUV.A-K5.

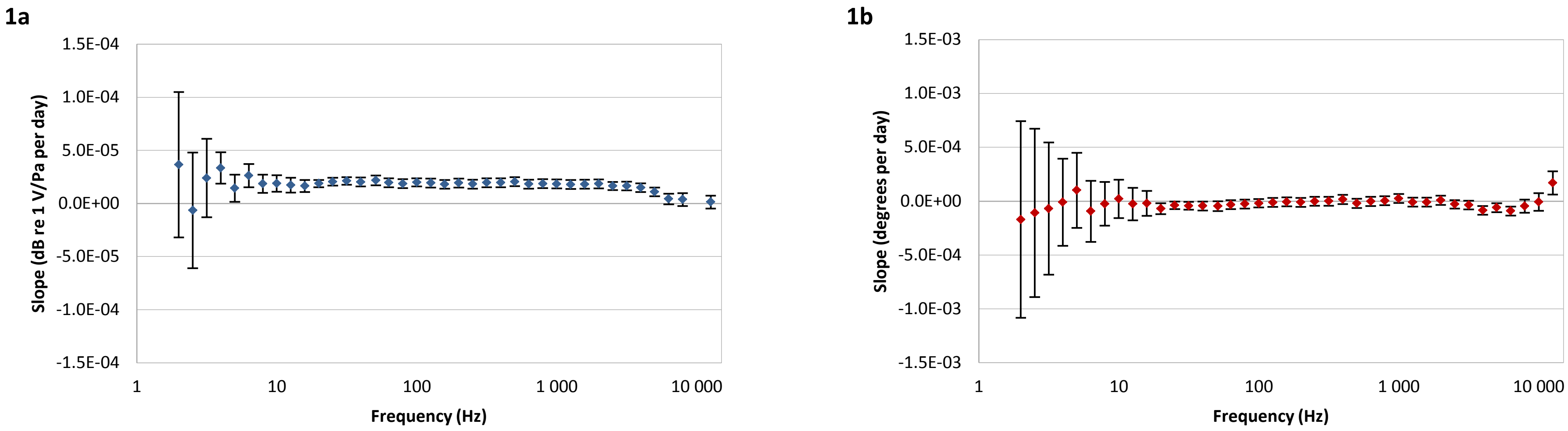


Figure 1. Stability of microphone 4160 s/n: 811014, indicated as the slope of change per day, modulus (1a) and phase (1b), plotted with uncertainties.

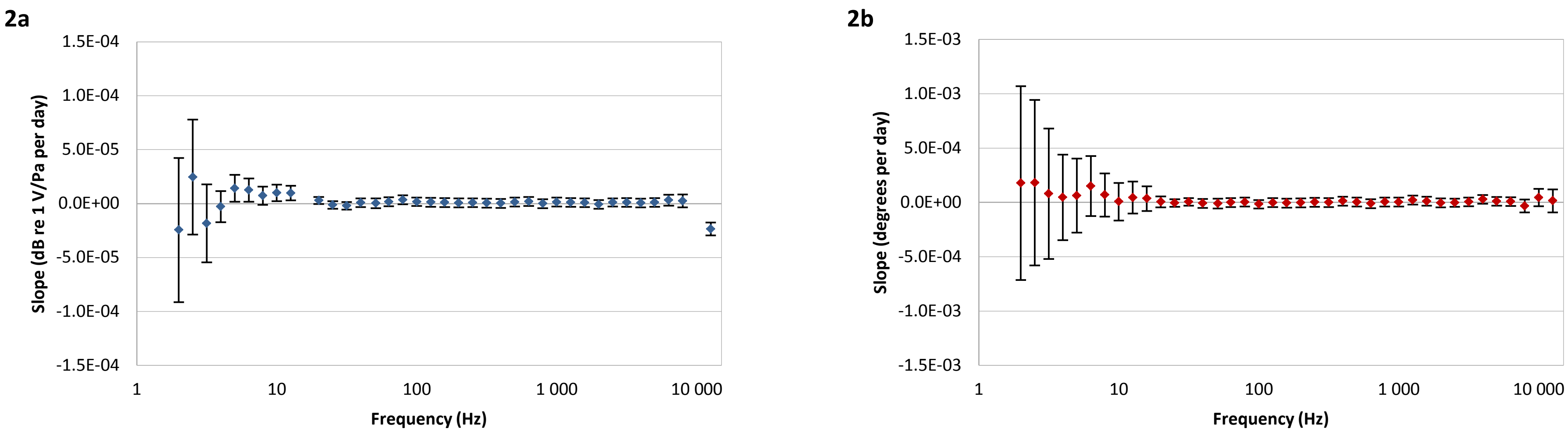


Figure 2. Stability of microphone 4160 s/n: 2036126, indicated as the slope of change per day, modulus (2a) and phase (2b), plotted with uncertainties.

6. Results reported

All NMIs reported their results in their standard certificate formats and by completing the reporting template. Only the results as reported in the reporting templates were used for calculation and reporting purposes of this comparison. It was the responsibility of the participating NMI to ensure that the data transfer was correct.

The technical protocol required all participants to report their results in accordance with the 2nd edition of IEC 61094-2, as published in 2009. CMI reported their results in accordance with the 1st edition of IEC 61094-2, as published in 1992 [6].

In addition to the modulus and phase results, all participants were required to report the microphone parameters of the two microphones.

Tables 2 and 3 indicate the reported values per microphone of each NMI.

Table 2. Microphone parameters reported by the participants for microphone 4160 s/n: 811014.

Microphone parameters 811014	**CMI**	**NMISA**	**NPL**	**VTT MIKES**	**Unit**
Front volume	553,195	537,5	532,7	526,736	mm^3
Front cavity depth	2,016	1,942	1,947	1,939	mm
Equivalent volume	136,0	143,4	150,224	155,5	mm^3
Excess front volume		81,8	154,044		mm^3
Resonant frequency	8,200	7,986	7,881	7,570	kHz
Loss factor	1,05	1,02	1,038	0,988	
Static pressure coefficient @ 250 Hz	-0,01600	-0,01697	-0,01530	-0,01527	dB/kPa
Temperature coefficient @ 250 Hz	-0,00200	-0,00170	-0,00280	-0,00191	dB/K

Table 3. Microphone parameters reported by the participants for microphone 4160 s/n: 2036126.

Microphone parameters 2036126	**CMI**	**NMISA**	**NPL**	**VTT MIKES**	**Unit**
Front volume	531,303	533,1	531,0	527,436	mm^3
Front cavity depth	1,936	1,958	1,958	1,952	mm
Equivalent volume	136,0	130,3	132,776	132,0	mm^3
Excess front volume		81,8	131,769		mm^3
Resonant frequency	8,200	8,856	8,164	8,457	kHz
Loss factor	1,05	1,03	1,056	0,954	
Static pressure coefficient @ 250 Hz	-0,01600	-0,01478	-0,01530	-0,01527	dB/kPa
Temperature coefficient @ 250 Hz	-0,00200	-0,00190	-0,00280	-0,00191	dB/K

All participants' results, modulus and phase, were analysed prior to the evaluation of the DoE for consistency. All results were found to be consistent.

Annex C reports on all the participant's results and their associated uncertainties.

7. Linking to Key Comparison Reference Values

Key Comparison Reference Values (KCRVs) were not determined for this comparison as in accordance with the CIPM MRA guidelines for RMO KCs. The DoEs were determined by linking this comparison's results to the CCAUV.A-K5 KCRVs [7, 8].

The linking of this comparison's results was performed by reference to the CCAUV.A-K5 results of NPL UK. The NMISA did participate in the CCAUV.A-K5 comparison, but due to NMISA not having results reported for the full scope of CCAUV.A-K5 and also having used a different calibration system, it was deemed appropriate not to use NMISA as a linking NMI for this comparison.

Since the sensitivity of microphone Brüel & Kjær 4160 s/n: 811014 shifted, its associated results have been excluded from the linking process.

Equation 1 is to be considered at each frequency of the reported complex sensitivities in this comparison, where $N = 4$ is the number of NMIs, identified by indices $i = 1, \dots, N$, that participated and the linking NMI being indexed by 1.

$$\boldsymbol{x_i = y + \Delta_i + \varepsilon_i} \tag{1}$$

where

x_i	reported sensitivity value (modulus or phase) provided by NMI i
y	estimate of the sensitivity (modulus or phase) for the microphone
Δ_i	estimate of the value component of the degree of equivalence for NMI i
ε_i	error associated with x_i

Here, ε_i is assumed to be a random draw from a normal distribution with expectation zero and standard deviation $u(x_i)$, the standard uncertainty associated with x_i reported by NMI i.

Additionally, for the linking NMI, Equation 2 is assumed for the value component of its DoE calculated in the CCAUV.A-K5 KC:

$$\boldsymbol{d_1 = \Delta_1 + \delta_1} \tag{2}$$

where

d_1	estimate of the value component of the DoE for the linking NMI
δ_1	error associated with d_1

Here, δ_1 is assumed to be a random draw from a normal distribution with expectation zero and standard deviation $u(d_1)$, the standard uncertainty associated with d_1 determined in the CCAUV.A-K5 KC.

Equation 3 defines the reference value, y, for the linking NMIs DoE. Equation 4 defines the linking NMI's results in the RMO comparison for the reference value, y, preserving the DoE for the linking NMI.

$$\boldsymbol{y = x_1 - d_1} \tag{3}$$

$$\boldsymbol{\Delta_1 = d_1} \tag{4}$$

Equation 5 defines the DoEs for the reported results of the participating NMIs, for NMIs with indices $i = 2, \dots, N$, this being the difference between the NMI's reported result and the reference value.

$$\boldsymbol{\Delta_i = x_i - y} \tag{5}$$

Furthermore, the uncertainties associated with the estimates are given by Equations 6, 7 and 8 for NMIs with indices $i = 2, \dots, N$.

$$\boldsymbol{u^2(y) = u^2(x_1) + u^2(d_1) - 2u(d_1, x_1)} \tag{6}$$

$$\boldsymbol{u^2(\Delta_1) = u^2(d_1)} \tag{7}$$

$$\boldsymbol{u^2(\Delta_i) = u^2(x_i) + u^2(y)} \tag{8}$$

The covariance between the DoE for the linking NMI and the results reported of the linking NMI in this RMO comparison can be quantified by identifying those effects that are common to the different measurements made by the linking NMI. Suppose that the CCAUV.A-K5 KCRV used as the basis for the DoEs is given by the inverse-variance weighted mean of the measured values $x_{j,0}, j = 1, \dots, N_0$, where the linking NMI that participated in this RMO KC is the first NMI in the CCAUV.A-K5 KC, and the remaining NMIs in the CCAUV.A-K5 KC did not participate in this RMO KC. Then, the value component of the DoE for the linking NMI is given by Equations 9 and 10.

$$\boldsymbol{d_1 = (1 - w_1)x_{1,0} - \sum_{j \neq 1} w_j x_{j,0}} \tag{9}$$

$$\boldsymbol{w_j = \frac{1/u^2(x_{j,0})}{\sum_n 1/u^2(x_{n,0})}} \tag{10}$$

Considering the reported results of the linking NMI in the CCAUV.A-K5 KC and the linking NMIs results in the RMO KC leads to Equations 11 and 12. The random components of the errors are different for each measurement made by the NMI and the systematic components are common to all measurements made by the NMI.

$$\boldsymbol{\varepsilon_{1,0} = \varepsilon_{1,0}^{R} + \varepsilon_{1}^{S}} \tag{11}$$

$$\boldsymbol{\varepsilon_{1} = \varepsilon_{1}^{R} + \varepsilon_{1}^{S}} \tag{12}$$

where

$\varepsilon_{1,0}^{\mathrm{R}}$	random components of $\varepsilon_{1,0}$
$\varepsilon_{1}^{\mathrm{R}}$	random components of ε_{1}
$\varepsilon_{1}^{\mathrm{S}}$	systematic components

The uncertainty associated to the linking NMI is then calculated as per Equation 13.

$$\boldsymbol{u(d_1, x_1) = (1 - w_1)u\left(x_{1,0}, x_1\right) = (1 - w_1)u^2\left(\varepsilon_1^S\right)} \tag{13}$$

8. Degrees of Equivalence

The DoEs with its associated uncertainty of measurement were calculated according to Section 7 and are the linked to the CCAUV.A-K5 KCRV.

Figures 3 to 6 illustrates the DoEs with respect to the CCAUV.A-K5 KCRVs, as determined for microphone 4160 s/n: 2036126 for each participating NMI. DoEs are only illustrated for results that were submitted by the participants.

Tables 4 and 5 shows the calculated DoEs with respect to the CCAUV.A-K5 KCRVs for modulus and phase and the associated uncertainty of the DOEs. DoEs are only illustrated for results that were submitted by the participants.

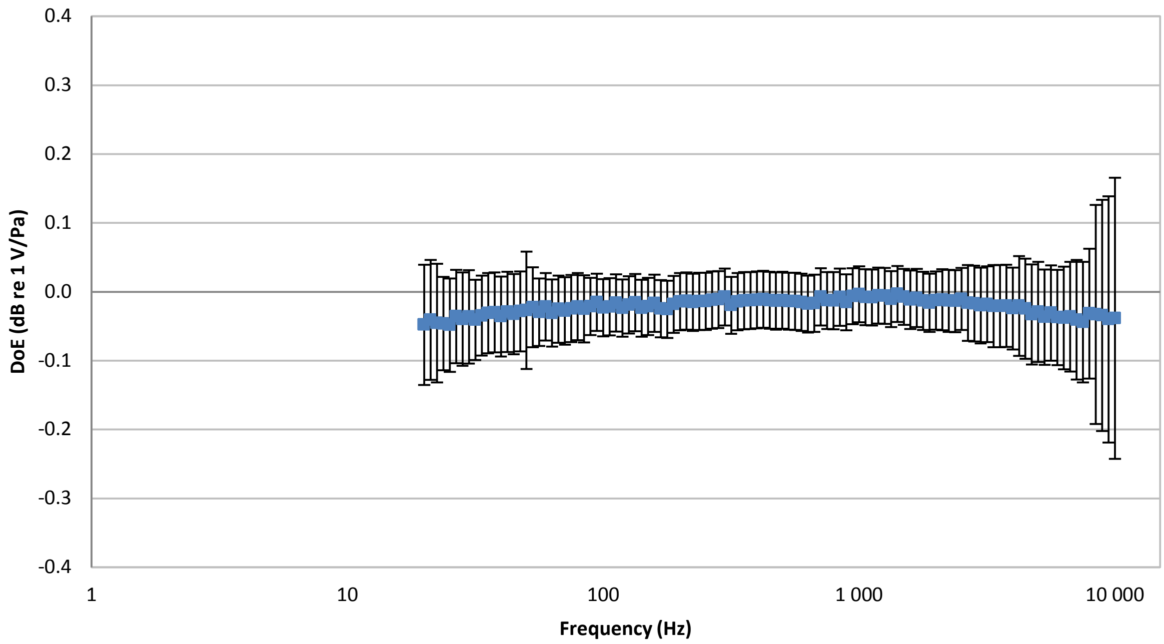
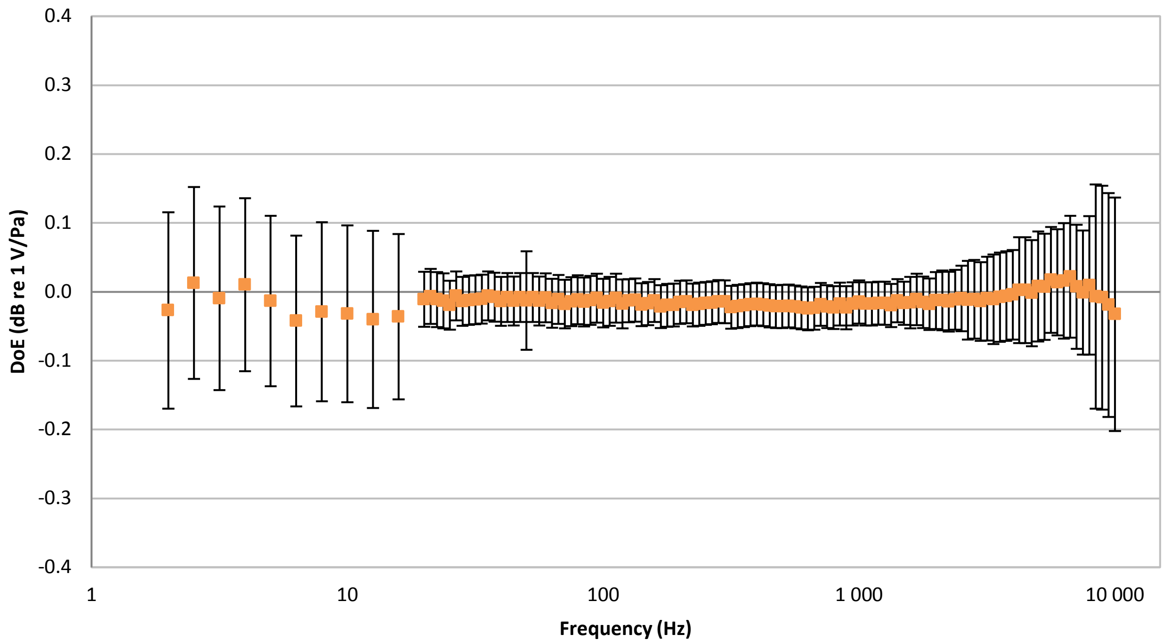
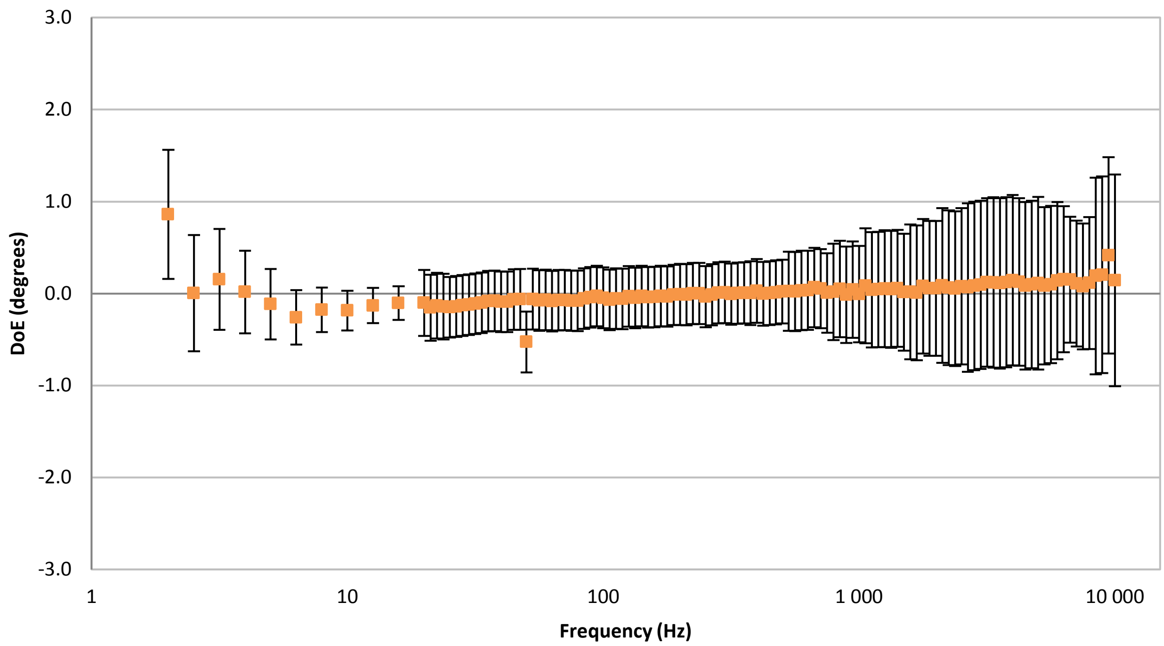


Figure 3. Calculated degrees of equivalence for CMI for modulus, microphone 4160 s/n: 2036126.

4a

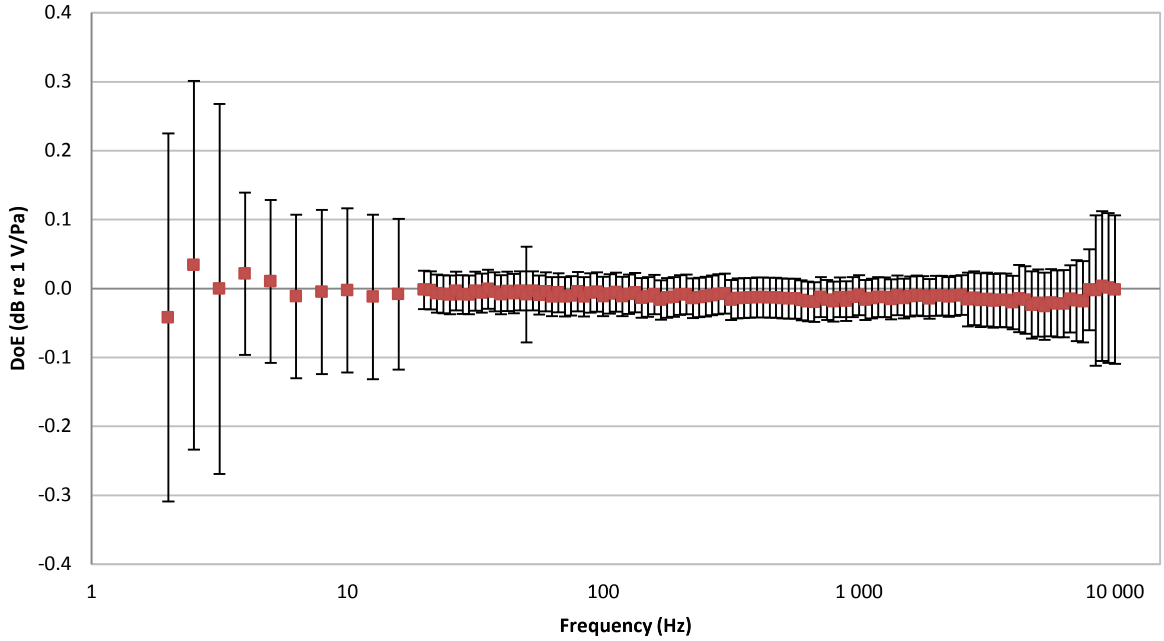


4b

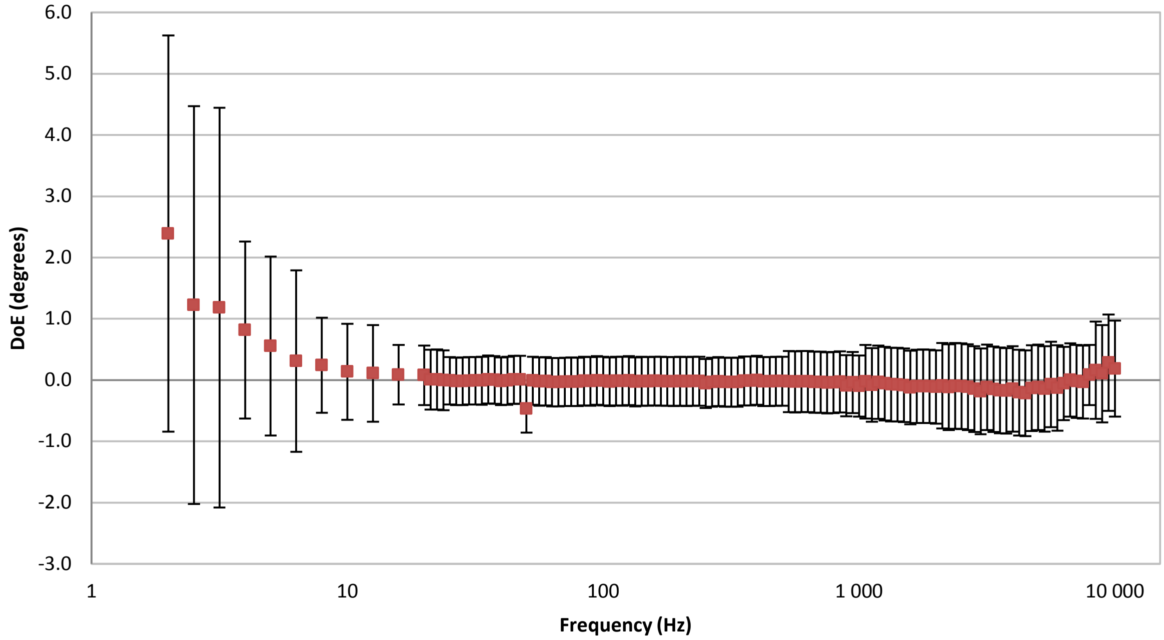


Figures 4. Calculated degrees of equivalence for NMISA for modulus (4a) and phase (4b), microphone 4160 s/n: 2036126.

5a



5b



Figures 5. Calculated degrees of equivalence for NPL for modulus (5a) and phase (5b), microphone 4160 s/n: 2036126.

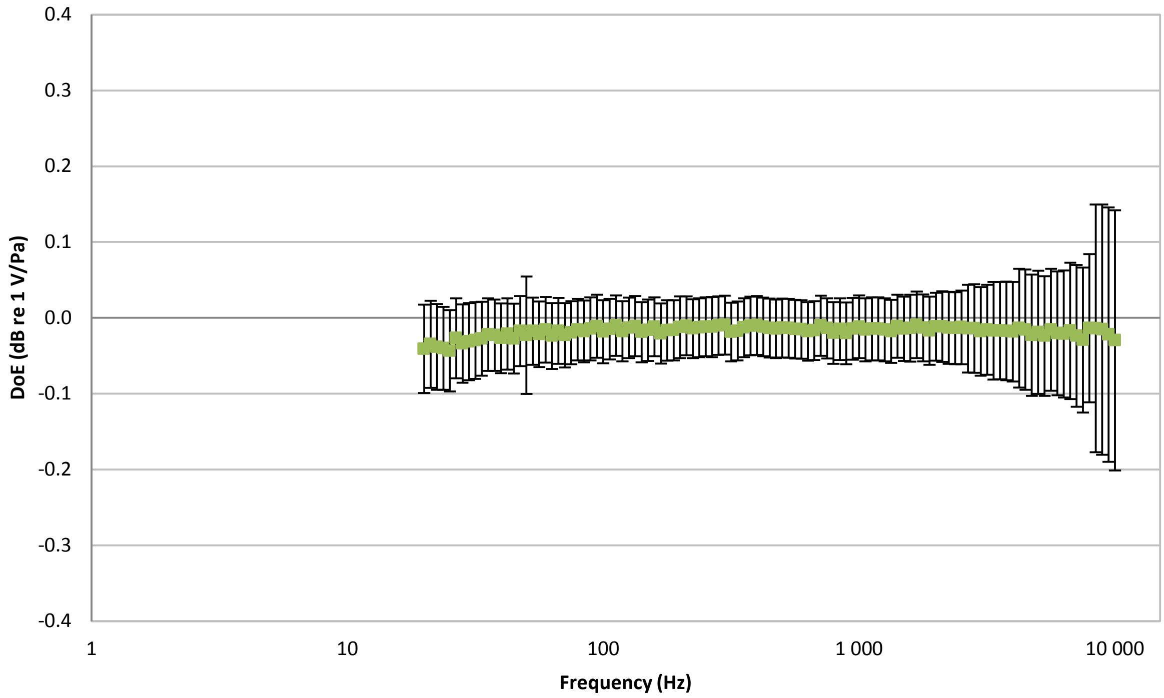


Figure 6. Calculated degrees of equivalence for VTT MIKES for modulus, microphone 4160 s/n: 2036126.

Table 4. Participant modulus DoEs with respect to CCAUV.A-K5 KCRVs.

Frequency (Hz)	CCAUV.A-K5 DoE (dB re 1V/Pa)					CCAUV.A-K5 U_{DoE} (dB re 1V/Pa)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
2,00		-0,027	-0,042				0,142	0,267	
2,51		0,013	0,034				0,139	0,268	
3,16		-0,010	-0,001				0,133	0,268	
3,98		0,010	0,021				0,126	0,118	
5,01		-0,014	0,010				0,124	0,118	
6,31		-0,042	-0,011				0,124	0,119	
7,94		-0,029	-0,005				0,130	0,119	
10,00		-0,032	-0,003				0,128	0,119	
12,59		-0,040	-0,012				0,129	0,119	
15,85		-0,036	-0,008				0,120	0,109	
19,95	-0,048	-0,011	-0,002	-0,041		0,087	0,040	0,028	0,058
21,13	-0,041	-0,007	-0,003	-0,035		0,087	0,040	0,028	0,057
22,39	-0,045	-0,011	-0,007	-0,038		0,086	0,040	0,028	0,056
23,71	-0,046	-0,013	-0,008	-0,040		0,068	0,040	0,028	0,055
25,12	-0,048	-0,019	-0,009	-0,043		0,068	0,036	0,028	0,054
26,61	-0,036	-0,006	-0,004	-0,027		0,068	0,036	0,028	0,053
28,18	-0,040	-0,014	-0,009	-0,034		0,068	0,036	0,028	0,052
29,85	-0,036	-0,012	-0,009	-0,031		0,068	0,036	0,028	0,051
31,62	-0,041	-0,012	-0,004	-0,030		0,058	0,036	0,028	0,051
33,50	-0,035	-0,011	-0,007	-0,028		0,058	0,035	0,028	0,049
35,48	-0,031	-0,006	-0,001	-0,022		0,058	0,035	0,028	0,048
37,58	-0,030	-0,008	-0,005	-0,023		0,058	0,035	0,028	0,047
39,81	-0,036	-0,014	-0,009	-0,027		0,058	0,035	0,028	0,046
42,17	-0,029	-0,008	-0,004	-0,021		0,058	0,035	0,028	0,047
44,67	-0,032	-0,013	-0,007	-0,027		0,058	0,035	0,028	0,046
47,32	-0,028	-0,008	-0,003	-0,017		0,058	0,036	0,028	0,046
50,12	-0,027	-0,013	-0,009	-0,023		0,085	0,072	0,069	0,077
53,09	-0,022	-0,008	-0,003	-0,017		0,058	0,036	0,028	0,044
56,23	-0,030	-0,014	-0,010	-0,022		0,049	0,036	0,028	0,043
59,57	-0,022	-0,009	-0,005	-0,016		0,049	0,036	0,028	0,043
63,10	-0,031	-0,017	-0,012	-0,024		0,049	0,036	0,028	0,043
66,83	-0,025	-0,011	-0,006	-0,017		0,049	0,036	0,028	0,043
70,79	-0,028	-0,018	-0,012	-0,023		0,049	0,035	0,029	0,042
74,99	-0,024	-0,014	-0,010	-0,019		0,049	0,035	0,029	0,042
79,43	-0,022	-0,012	-0,005	-0,016		0,049	0,035	0,029	0,041
84,14	-0,025	-0,015	-0,012	-0,018		0,049	0,035	0,029	0,041
89,13	-0,021	-0,012	-0,006	-0,014		0,042	0,035	0,029	0,042
94,41	-0,015	-0,009	-0,005	-0,011		0,042	0,035	0,029	0,042
100,00	-0,023	-0,016	-0,011	-0,018		0,042	0,035	0,029	0,042
105,93	-0,022	-0,014	-0,008	-0,015		0,042	0,035	0,029	0,040
112,20	-0,016	-0,009	-0,005	-0,010		0,042	0,035	0,029	0,040
118,85	-0,024	-0,018	-0,012	-0,018		0,042	0,035	0,029	0,040
125,89	-0,019	-0,013	-0,008	-0,013		0,042	0,031	0,029	0,040
133,35	-0,016	-0,012	-0,006	-0,011		0,042	0,031	0,029	0,040
141,25	-0,024	-0,019	-0,014	-0,019		0,041	0,031	0,029	0,040
149,62	-0,021	-0,017	-0,012	-0,016		0,041	0,031	0,029	0,041
158,49	-0,017	-0,013	-0,009	-0,012		0,041	0,031	0,029	0,039
167,88	-0,025	-0,022	-0,017	-0,021		0,041	0,031	0,029	0,040
177,83	-0,026	-0,020	-0,014	-0,017		0,041	0,031	0,029	0,040
188,36	-0,018	-0,019	-0,012	-0,016		0,041	0,031	0,029	0,040

Frequency (Hz)	CCAUV.A-K5 DoE (dB re 1V/Pa)					CCAUV.A-K5 U_{DoE} (dB re 1V/Pa)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
199,53	-0,014	-0,015	-0,009	-0,012		0,041	0,031	0,029	0,041
211,35	-0,014	-0,015	-0,009	-0,011		0,041	0,031	0,029	0,039
223,87	-0,015	-0,019	-0,014	-0,014		0,041	0,031	0,029	0,039
237,14	-0,014	-0,018	-0,013	-0,013		0,041	0,031	0,029	0,039
251,19	-0,014	-0,017	-0,012	-0,012		0,041	0,031	0,029	0,039
266,07	-0,012	-0,016	-0,010	-0,012		0,041	0,031	0,029	0,040
281,84	-0,011	-0,014	-0,008	-0,010		0,041	0,031	0,029	0,039
298,54	-0,007	-0,014	-0,007	-0,009		0,041	0,031	0,029	0,039
316,23	-0,020	-0,023	-0,017	-0,019		0,041	0,031	0,029	0,039
334,97	-0,014	-0,021	-0,014	-0,017		0,041	0,031	0,029	0,039
354,81	-0,013	-0,020	-0,014	-0,013		0,041	0,031	0,029	0,039
375,84	-0,013	-0,019	-0,014	-0,011		0,041	0,031	0,029	0,039
398,11	-0,012	-0,018	-0,013	-0,010		0,041	0,031	0,029	0,039
421,70	-0,011	-0,019	-0,013	-0,012		0,041	0,031	0,029	0,039
446,68	-0,012	-0,020	-0,013	-0,013		0,041	0,031	0,029	0,039
473,15	-0,013	-0,021	-0,013	-0,014		0,041	0,031	0,029	0,039
501,19	-0,012	-0,021	-0,014	-0,013		0,041	0,031	0,029	0,039
530,88	-0,014	-0,021	-0,015	-0,014		0,041	0,031	0,029	0,039
562,34	-0,014	-0,022	-0,015	-0,015		0,041	0,031	0,029	0,039
595,66	-0,015	-0,023	-0,017	-0,015		0,041	0,031	0,029	0,039
630,96	-0,018	-0,025	-0,019	-0,018		0,041	0,031	0,029	0,039
668,34	-0,017	-0,024	-0,020	-0,017		0,041	0,031	0,029	0,039
707,95	-0,007	-0,018	-0,012	-0,010		0,041	0,031	0,029	0,040
749,89	-0,013	-0,022	-0,017	-0,014		0,041	0,031	0,029	0,040
794,33	-0,013	-0,023	-0,019	-0,020		0,042	0,031	0,029	0,041
841,40	-0,008	-0,018	-0,013	-0,015		0,042	0,031	0,029	0,041
891,25	-0,015	-0,023	-0,018	-0,020		0,041	0,031	0,029	0,041
944,06	-0,007	-0,018	-0,013	-0,015		0,041	0,031	0,029	0,041
1 000,0	-0,004	-0,015	-0,010	-0,012		0,041	0,031	0,029	0,042
1 059,3	-0,008	-0,018	-0,017	-0,016		0,041	0,031	0,029	0,042
1 122,0	-0,008	-0,017	-0,014	-0,014		0,041	0,031	0,029	0,042
1 188,5	-0,005	-0,016	-0,012	-0,014		0,041	0,031	0,029	0,042
1 258,9	-0,006	-0,017	-0,013	-0,016		0,041	0,031	0,029	0,042
1 333,5	-0,011	-0,020	-0,016	-0,018		0,041	0,031	0,029	0,042
1 412,5	-0,003	-0,013	-0,010	-0,011		0,041	0,031	0,029	0,042
1 496,2	-0,008	-0,017	-0,015	-0,015		0,041	0,031	0,029	0,042
1 584,9	-0,012	-0,016	-0,012	-0,014		0,042	0,037	0,029	0,044
1 678,8	-0,009	-0,011	-0,010	-0,009		0,042	0,037	0,029	0,044
1 778,3	-0,013	-0,015	-0,011	-0,013		0,042	0,037	0,029	0,044
1 883,6	-0,016	-0,018	-0,015	-0,017		0,042	0,037	0,029	0,045
1 995,3	-0,013	-0,013	-0,011	-0,012		0,042	0,041	0,029	0,045
2 113,5	-0,011	-0,012	-0,010	-0,011		0,044	0,043	0,029	0,047
2 238,7	-0,013	-0,014	-0,012	-0,013		0,045	0,043	0,029	0,048
2 371,4	-0,014	-0,012	-0,011	-0,014		0,045	0,043	0,029	0,048
2 511,9	-0,011	-0,010	-0,010	-0,013		0,045	0,048	0,029	0,048
2 660,7	-0,016	-0,012	-0,016	-0,014		0,055	0,057	0,039	0,058
2 818,4	-0,017	-0,011	-0,014	-0,014		0,055	0,057	0,039	0,059
2 985,4	-0,020	-0,014	-0,017	-0,018		0,055	0,057	0,039	0,059
3 162,3	-0,018	-0,010	-0,016	-0,016		0,055	0,061	0,039	0,059
3 349,7	-0,021	-0,011	-0,018	-0,017		0,060	0,065	0,039	0,064
3 548,1	-0,021	-0,008	-0,017	-0,017		0,060	0,065	0,039	0,064

Frequency (Hz)	CCAUV.A-K5 DoE (dB re 1V/Pa)					CCAUV.A-K5 U_{DoE} (dB re 1V/Pa)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
3 758,4	-0,020	-0,006	-0,017	-0,017		0,060	0,065	0,039	0,065
3 981,1	-0,024	-0,004	-0,020	-0,018		0,060	0,065	0,039	0,066
4 217,0	-0,021	0,002	-0,015	-0,014		0,073	0,077	0,049	0,078
4 466,8	-0,025	0,002	-0,017	-0,016		0,073	0,077	0,049	0,079
4 731,5	-0,033	-0,002	-0,024	-0,023		0,073	0,077	0,049	0,080
5 011,9	-0,029	0,008	-0,021	-0,019		0,073	0,080	0,049	0,081
5 308,8	-0,037	0,007	-0,026	-0,024		0,069	0,077	0,049	0,079
5 623,4	-0,031	0,017	-0,021	-0,016		0,069	0,077	0,049	0,080
5 956,6	-0,037	0,014	-0,022	-0,020		0,069	0,077	0,049	0,082
6 309,6	-0,038	0,016	-0,022	-0,021		0,074	0,084	0,049	0,084
6 683,4	-0,036	0,022	-0,015	-0,017		0,080	0,088	0,049	0,090
7 079,5	-0,041	0,007	-0,018	-0,024		0,087	0,090	0,059	0,094
7 498,9	-0,044	-0,001	-0,019	-0,029		0,087	0,090	0,059	0,096
7 943,3	-0,032	0,009	-0,002	-0,014		0,094	0,101	0,059	0,098
8 414,0	-0,033	-0,007	-0,003	-0,014		0,159	0,163	0,109	0,163
8 912,5	-0,034	-0,008	0,004	-0,015		0,168	0,163	0,109	0,165
9 440,6	-0,040	-0,019	0,001	-0,022		0,179	0,162	0,109	0,168
10 000	-0,039	-0,033	-0,002	-0,030		0,204	0,170	0,108	0,172

Table 5. Participant phase DoEs with respect to CCAUV.A-K5 KCRVs.

Frequency (Hz)	CCAUV.A-K5 DoE (degrees)					CCAUV.A-K5 U_{DoE} (degrees)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
2,00		0,86	2,39				0,70	3,23	
2,51		0,00	1,22				0,63	3,25	
3,16		0,15	1,18				0,55	3,26	
3,98		0,02	0,82				0,45	1,44	
5,01		-0,11	0,56				0,38	1,46	
6,31		-0,26	0,31				0,30	1,48	
7,94		-0,18	0,24				0,24	0,78	
10,00		-0,18	0,14				0,22	0,78	
12,59		-0,13	0,11				0,19	0,79	
15,85		-0,10	0,09				0,18	0,48	
19,95		-0,10	0,08				0,36	0,49	
21,13		-0,15	0,01				0,36	0,49	
22,39		-0,13	0,01				0,36	0,49	
23,71		-0,14	0,00				0,36	0,49	
25,12		-0,15	-0,01				0,33	0,39	
26,61		-0,14	-0,02				0,33	0,39	
28,18		-0,13	-0,02				0,33	0,39	
29,85		-0,12	-0,01				0,33	0,39	
31,62		-0,11	-0,01				0,33	0,39	
33,50		-0,10	-0,01				0,33	0,39	
35,48		-0,08	0,01				0,33	0,39	
37,58		-0,08	0,00				0,33	0,39	
39,81		-0,09	-0,02				0,33	0,39	
42,17		-0,09	-0,01				0,33	0,39	
44,67		-0,06	0,01				0,33	0,39	
47,32		-0,06	0,01				0,33	0,39	
50,12		-0,53	-0,47				0,33	0,39	
53,09		-0,06	-0,01				0,33	0,39	
56,23		-0,08	-0,03				0,33	0,39	
59,57		-0,07	-0,02				0,33	0,39	
63,10		-0,08	-0,03				0,33	0,39	
66,83		-0,07	-0,03				0,33	0,39	
70,79		-0,07	-0,03				0,33	0,40	
74,99		-0,08	-0,03				0,33	0,40	
79,43		-0,08	-0,03				0,33	0,40	
84,14		-0,06	-0,02				0,33	0,40	
89,13		-0,04	-0,02				0,33	0,40	
94,41		-0,03	-0,01				0,33	0,40	
100,00		-0,05	-0,02				0,33	0,40	
105,93		-0,07	-0,03				0,33	0,40	
112,20		-0,06	-0,02				0,33	0,40	
118,85		-0,06	-0,02				0,33	0,40	
125,89		-0,03	-0,01				0,33	0,40	
133,35		-0,05	-0,03				0,33	0,40	
141,25		-0,03	-0,02				0,33	0,40	
149,62		-0,04	-0,02				0,33	0,40	
158,49		-0,04	-0,02				0,33	0,40	
167,88		-0,03	-0,02				0,33	0,40	
177,83		-0,03	-0,02				0,33	0,40	
188,36		-0,01	-0,02				0,33	0,40	

Frequency (Hz)	CCAUV.A-K5 DoE (degrees)					CCAUV.A-K5 U_{DoE} (degrees)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
199,53		-0,01	-0,02				0,33	0,40	
211,35		-0,01	-0,02				0,33	0,40	
223,87		0,00	-0,02				0,33	0,40	
237,14		0,00	-0,02				0,33	0,40	
251,19		-0,03	-0,05				0,33	0,40	
266,07		-0,01	-0,03				0,33	0,40	
281,84		0,01	-0,02				0,33	0,40	
298,54		0,01	-0,04				0,33	0,40	
316,23		-0,01	-0,04				0,33	0,40	
334,97		0,01	-0,03				0,33	0,40	
354,81		0,01	-0,01				0,33	0,40	
375,84		0,00	-0,02				0,35	0,40	
398,11		0,03	0,00				0,35	0,40	
421,70		0,00	-0,02				0,35	0,40	
446,68		0,00	-0,03				0,35	0,40	
473,15		0,01	-0,02				0,35	0,40	
501,19		0,02	-0,02				0,35	0,40	
530,88		0,03	-0,02				0,43	0,50	
562,34		0,02	-0,03				0,43	0,50	
595,66		0,03	-0,03				0,43	0,50	
630,96		0,04	-0,02				0,43	0,50	
668,34		0,07	-0,03				0,43	0,50	
707,95		0,05	-0,04				0,43	0,50	
749,89		0,01	-0,04				0,43	0,50	
794,33		0,02	-0,04				0,52	0,50	
841,40		0,05	-0,03				0,52	0,50	
891,25		-0,01	-0,09				0,52	0,50	
944,06		0,04	-0,04				0,52	0,50	
1 000,0		-0,01	-0,10				0,52	0,50	
1 059,3		0,08	-0,03				0,63	0,60	
1 122,0		0,04	-0,08				0,63	0,60	
1 188,5		0,04	-0,04				0,63	0,60	
1 258,9		0,05	-0,06				0,64	0,60	
1 333,5		0,05	-0,07				0,64	0,60	
1 412,5		0,06	-0,07				0,64	0,60	
1 496,2		0,02	-0,08				0,64	0,60	
1 584,9		0,02	-0,12				0,73	0,60	
1 678,8		0,01	-0,10				0,73	0,60	
1 778,3		0,08	-0,10				0,73	0,60	
1 883,6		0,06	-0,10				0,73	0,60	
1 995,3		0,06	-0,11				0,73	0,60	
2 113,5		0,09	-0,09				0,84	0,70	
2 238,7		0,06	-0,12				0,84	0,70	
2 371,4		0,05	-0,10				0,84	0,70	
2 511,9		0,08	-0,10				0,85	0,70	
2 660,7		0,07	-0,11				0,92	0,70	
2 818,4		0,08	-0,15				0,92	0,70	
2 985,4		0,09	-0,19				0,92	0,70	
3 162,3		0,12	-0,12				0,92	0,70	
3 349,7		0,12	-0,15				0,93	0,70	
3 548,1		0,11	-0,17				0,93	0,70	

Frequency (Hz)	CCAUV.A-K5 DoE (degrees)					CCAUV.A-K5 U_{DoE} (degrees)			
	CMI	NMISA	NPL	MIKES		CMI	NMISA	NPL	MIKES
3 758,4		0,12	-0,18				0,93	0,70	
3 981,1		0,14	-0,15				0,93	0,70	
4 217,0		0,13	-0,20				0,91	0,70	
4 466,8		0,08	-0,22				0,91	0,70	
4 731,5		0,10	-0,13				0,91	0,70	
5 011,9		0,11	-0,12				0,94	0,70	
5 308,8		0,08	-0,15				0,85	0,70	
5 623,4		0,10	-0,07				0,85	0,70	
5 956,6		0,14	-0,13				0,85	0,70	
6 309,6		0,15	-0,06				0,79	0,60	
6 683,4		0,15	0,00				0,68	0,60	
7 079,5		0,11	-0,02				0,68	0,60	
7 498,9		0,08	-0,03				0,68	0,60	
7 943,3		0,11	0,08				0,72	0,49	
8 414,0		0,19	0,16				1,07	0,79	
8 912,5		0,20	0,10				1,07	0,79	
9 440,6		0,41	0,28				1,07	0,79	
10 000		0,15	0,19				1,15	0,78	

9. Analysis of results

All the results were evaluated for outliers once the DoEs were established. Outliers were defined as when the DoE value extended by the DoEs associated expanded uncertainty of measurement did not overlap with the linked reference value.

Outliers were identified for NMISA for phase sensitivities at frequencies 2 Hz and 50 Hz. NMISA, as the pilot NMI, opted not to resubmit results for the phase sensitivity at 2 Hz. The outlying 50 Hz phase sensitivity result is due to NPL UKs phase sensitivity DoE at 50 Hz achieved in the CCAUV.A-K5 KC. This was caused by 50 Hz mains line interference issue which was subsequently addressed before participating in this comparison. The NMISA outlying 50 Hz phase sensitivity result is technically therefore not to be considered as an outlying result.

As the 50 Hz mains line interference also affected the modulus result of the NPL UK at 50 Hz, the associated uncertainties for all the 50 Hz modulus DoEs were also affected.

10. Conclusion

The comparison is considered successful in achieving the objectives of establishing measurement equivalence in support of CMCs for LS1P microphones that are calibrated via the pressure reciprocity calibration technique.

11. Acknowledgements

The pilot NMI hereby acknowledges and appreciates all the participating NMIs time and efforts in contributing to this comparison.

The valuable contributions made by the NPL UK is acknowledged and highly appreciated.

12. References

[1] J. Avison and R. G. Barham, "Final report on key comparison CCAUV.A-K5: pressure calibration of laboratory standard microphones in the frequency range 2 Hz to 10 kHz," *Metrologia*, vol. 51, pp. 09007, 2014.

[2] R. Nel, "Technical protocol for the regional key comparison AFRIMETS.AUV.A-K5: Primary pressure calibration of LS1P microphones according to IEC 61094-2, over the frequency range 2 Hz to 10 kHz," NMISA, South Africa, Tech. Rep. NMISA-15-00070, 2015.

[3] Measurement Microphones - Part 2: Primary Method for Pressure Calibration of Laboratory Standard Microphones by the Reciprocity Technique, IEC 61094-2, 2009.

[4] J. Avison, "Technical protocol: Key comparison of pressure calibration of LS1P microphones (EURAMET.AUV.A-K5)," NPL, United Kingdom, Tech. Rep. EURAMET.AUV.A-K5, 2013.

[5] “Measurement Comparisons in the CIPM MRA,” International Committee for Weights and Measures, CIPM MRA-D-05, 2016.

[6] Measurement Microphones - Part 2: Primary Method for Pressure Calibration of Laboratory Standard Microphones by the Reciprocity Technique, IEC 61094-2, 1992.

[7] B. Toman and A. Possolo, "Laboratory effects models for interlaboratory comparisons," *Accred. Qual. Assur.*, vol. 14, pp. 553-563, 2009.

[8] D. R. White, "On the analysis of measurement comparisons," *Metrologia*, vol. 41, pp. 122-131, 2004.

Annex A – Participant Capabilities

An agreement to participate questionnaire was circulated to all CCAUV -and AFRIMETS AUV members before the comparison was registered and Table A.1 illustrates the ranges and parameters of all the participant responses received.

Table A.1. Parameter summary of the participants.

Frequency	**NMI**			
Range	**CMI**	**VTT MIKES**	**NPL**	**NMISA**
2 Hz to 20 Hz			❶ & ❷	❶ & ❷
20 Hz to 10 kHz	❶	❶	❶ & ❷	❶ & ❷

Parameter keys
❶ Modulus
❷ Phase

Annex B – Participant Methods

NOTE References that appear in the descriptions of a participant's method description and uncertainty matrix does not form part of the main body of text in this report. The reported wording is exactly as reported by each participant.

B.1 CMI

According to IEC 61094-2 (1992). The standard microphones were calibrated by Reciprocity Calibration System BK 9699; incl. 5998 unit, Pulse A/D-D/A conversion unit, Reciprocity measurement Program WT 9708 ver. 1.008 and AT/BK Microphone pressure sensitivity calibration calculation program ver. 3.0.

For determining the microphone front volume used two couplers; CPL4144 (2040 mm3) and CPL4148 (4074 mm3). From the both results of the different calibrations was calculated microphone front volume.

Before calibration we calibrated capacity of sender unit.

Calibration was performed at the exact 1/12th-octave frequencies from 19.953 Hz to 10 kHz. Due to the limited number of measurement frequencies of used software, measurements were divided into three measuring ranges due to the limited number of measuring frequencies in WT 9708 software; from 19.953 Hz to 178 Hz & 251 Hz, from 188 Hz to 1.5 kHz & 251 Hz and from 1.58 kHz to 10 kHz & 251 Hz. The measurements was performed under climatic conditions: Temperature range from 22.2 °C to 22.6 °C, relative humidity range from 30% to 40% and atmospheric pressure in range from 100.3 kPa to 101.1 kPa. Current atmospheric pressure was defined for each measurement sequence. Microphone lump parameters were defined as nominal parameters. LS1p microphone front volume was determined using the approximation of the difference of sensitivity to zero from measurements with two different couplers; 4144 and 4148. Front cavity depth was determined using front volume divided by 274.4.

B.2 NPL

The effective volumes and cavity depths of the microphones were measured and nominal values were assumed for the acoustical impedance parameters unless historical measurement data was available. The uncertainties were calculated assuming nominal acoustical impedance parameter values were used in either case. The models for the temperature and pressure coefficients given in IEC 61094-2:2009 were used to correct the results to reference environment conditions. This requires the low-frequency value for the temperature and pressure coefficients, which are shown in Tables 2 and 3 below, and the resonance frequency, which was calculated from the acoustical compliance and mass parameters, shown in Table 1.

The uncertainty data given in the certificate is that from NPL's ISO 17025 accredited calibration service. The components of this uncertainty are shown in the accompanying spreadsheet Uncertainties Summary Sheet issue 9 modified for EURAMET_AUV_A-K5 2013.xls. The overall uncertainty has been determined by combining the components according to the ISO Guide (GUM) and rounding-up the final figure to the nearest 0.01 dB and 0.1 degrees for level and phase estimates, respectively.

The effects of non-radial motion inside the coupler have been accounted for by correction for sensitivity level, but have not been considered for phase, nor has an uncertainty component been determined for the effect on phase. The effect of heat conduction in the coupler on sensitivity level and phase has been accounted for by the "Broadband" correction of IEC 61094-2:2009 annex A.3 (see additional notes below). The coupler used for the measurements did not have capillary tubes, and sealing was achieved by a constant applied force and without sealant.

Because measurements made at 50.1 Hz were affected by mains noise, measurements were performed at 51.0 Hz in place of 50.1 Hz. Interpolation was used to estimate the differences in both the sensitivity level and the sensitivity phase between 51.0 Hz and 50.1 Hz for each of the two microphones. The estimates were then added as components to the sensitivity level and sensitivity phase uncertainty budgets for the 50.1 Hz frequency. The additional uncertainty components were found to have no effect on the overall uncertainties at this frequency.

Microphone Parameter	Microphone 4160 811014	Microphone 4160 2036126
Effective volume (mm^3)	533.0	531.0
Cavity depth (mm)	1.947	1.958
Acoustical mass (kg m^{-4})	385.1	406
Acoustical compliance (N^{-1} m^5)	10.059×10^{-13}	9.360×10^{-13}
Acoustical resistance (N s m^{-5})	1.98×10^7	2.20×10^7

Table 1   Microphone parameters

Changes to the NPL uncertainty budget since CCAUV.A-K5.

The following discussion relates to changes in the uncertainty budget that has been submitted in an accompanying spreadsheet, and to which the reader is now referred.

Since the NPL uncertainty budget was submitted for CCAUV.A-K5, we have had cause to revise the values for a number of components. These revised uncertainties were used for key comparison EURAMET.AUV.A-K5 which followed CCAUV.A-K5 and preceded AFRIMETS.AUV.A-K5.

The changes to the 'Resistor Box Accuracy – Capacitor' and 'Stray Capacitance' uncertainty components since the last version were due to:

- correction of some double counting
- A slightly lower uncertainty on stray capacitance value due to better data being available
- A new component being introduced to cover departure from ideal parallel RC circuit

Changes to the 'Linearity' component in the phase uncertainty budget are due to additional measurement data being available. The original component was based on the first measurement of the lock-in-amplifiers' phase measurement linearity. Since then we have generated three additional measurements (at one year intervals) and all show much smaller deviations across phase angles. We believe these measurements are a truer reflection of the behaviour of the device because they were performed in-situ in the microphone calibration lab, unlike the original measurement. We are confident that the reduced variability is sustainable because the results have been repeatable for three successive years. It therefore seems reasonable to reduce the size of the component to reflect the three more recent measurements.

Changes in the total uncertainties for the phase measurement are restricted to 1 kHz and 6.3 kHz alone. However, we have not applied these reduced uncertainties to our AFRIMETS.AUV.A-K5 results, because these frequencies are within the range of our ISO 17025 accreditation scope and we cannot therefore issue certificates quoting uncertainties lower than those declared under this accreditation.

Changes in the total uncertainties for the magnitude (level) measurements are restricted to frequencies below 20 Hz.

Additional notes:

IEC 61094-2:2009 Annex A provides two models for the heat conduction correction, the Low Frequency Solution and the Broadband Solution. Analysis has revealed significant differences in behaviour between the models at very low frequencies, leading to inconsistency in calibration results. Once a resolution is found it may be desirable to reapply a heat conduction correction to the key comparison results on a retrospective basis.

Research carried out by NPL over the last 2 years [Jackett (2014), Metrologia 51, 423] indicates that the Broadband solution is flawed at low frequency due to an error in accounting for heat conduction through the coupler terminations. The error is significant in both level and phase and increases with decreasing frequency. It may ultimately be possible to devise a solution that incorporates both heat conduction and viscous losses, but until that time the use of the low frequency solution is the preferred option for reciprocity calibration at low frequencies.

However, in the interests of achieving consistency between the AFRIMETS.A-K5 and CCAUV.A-K5 intercomparisons, NPL have continued using the Broadband solution, which was in place before the research described above was undertaken.

Frequency (Hz)	Temperature Correction dB/K	deg/K	Pressure Correction dB/kPa	deg/kPa
1.995	-0.0027	0.0000	-0.0155	0.0000
3.98	-0.0027	0.0000	-0.0155	0.0000
7.94	-0.0027	0.0000	-0.0155	0.0000
15.85	-0.0027	0.0000	-0.0155	0.0000
31.6	-0.0027	0.0000	-0.0155	0.0000
63.1	-0.0027	0.0000	-0.0155	0.0000
125.9	-0.0027	0.0000	-0.0155	0.0000
251	-0.0027	0.0000	-0.0155	0.0000
501	-0.0027	0.0000	-0.0155	0.0000
1000	-0.0033	-0.0120	-0.0147	0.0087
1995	-0.0043	-0.0213	-0.0139	0.0160
2510	-0.0053	-0.0253	-0.0126	0.0173
3160	-0.0070	-0.0285	-0.0099	0.0156
3980	-0.0096	-0.0264	-0.0057	0.0050
5010	-0.0130	-0.0087	-0.0008	-0.0281
6310	-0.0155	0.0386	0.0007	-0.1013
7940	-0.0129	0.1094	-0.0084	-0.1989
10000	0.0000	0.1214	-0.0308	-0.2078
12590	0.0006	0.0290	-0.0388	-0.0517

Table 2 Microphone 4160 811012 Environmental Correction

Frequency (Hz)	Temperature Correction dB/K	deg/K	Pressure Correction dB/kPa	deg/kPa
1.995	-0.0027	0.0000	-0.0155	0.0000
3.98	-0.0027	0.0000	-0.0155	0.0000
7.94	-0.0027	0.0000	-0.0155	0.0000
15.85	-0.0027	0.0000	-0.0155	0.0000
31.6	-0.0027	0.0000	-0.0155	0.0000
63.1	-0.0027	0.0000	-0.0155	0.0000
125.9	-0.0027	0.0000	-0.0155	0.0000
251	-0.0027	0.0000	-0.0155	0.0000
501	-0.0027	0.0000	-0.0155	0.0000
1000	-0.0033	-0.0116	-0.0147	0.0083
1995	-0.0042	-0.0207	-0.0140	0.0156
2510	-0.0051	-0.0247	-0.0128	0.0172
3160	-0.0066	-0.0282	-0.0104	0.0163
3980	-0.0091	-0.0274	-0.0064	0.0076
5010	-0.0125	-0.0131	-0.0015	-0.0208
6310	-0.0153	0.0292	0.0010	-0.0872
7940	-0.0139	0.0990	-0.0060	-0.1855
10000	-0.0025	0.1300	-0.0271	-0.2188
12590	0.0051	0.0168	-0.0409	-0.0771

Table 3 Microphone 4160 2652754 Environmental Correction

Capacitance determination for NPL's microphone pressure reciprocity system

Equivalent capacitance value of impedance box channel 13 (capacitor)

The NPL reciprocity calibration system uses one of a set of calibrated resistors placed in series with the transmitter microphone, to determine the driving electrical current. Different resistance values are needed at different frequency so that the voltage across the resistor is approximately equal to the open-circuit output voltage of the receiver microphone. This reduces the linearity requirements of the measurement channel, and the associated uncertainty. However at frequencies below 20 Hz, many more resistor values would be needed, and the resistance values becomes excessively large. Hence, a single calibrated capacitor is used to cover this frequency range. These components are housed in a combined resistor box and switching unit, which has 12 resistor channels and 1 capacitor channel.

1.1 Capacitance

The capacitance can be determined by comparison with an equivalent magnitude measurement made via the calibrated resistors, by comparing the idealised values of their respective RC circuits.

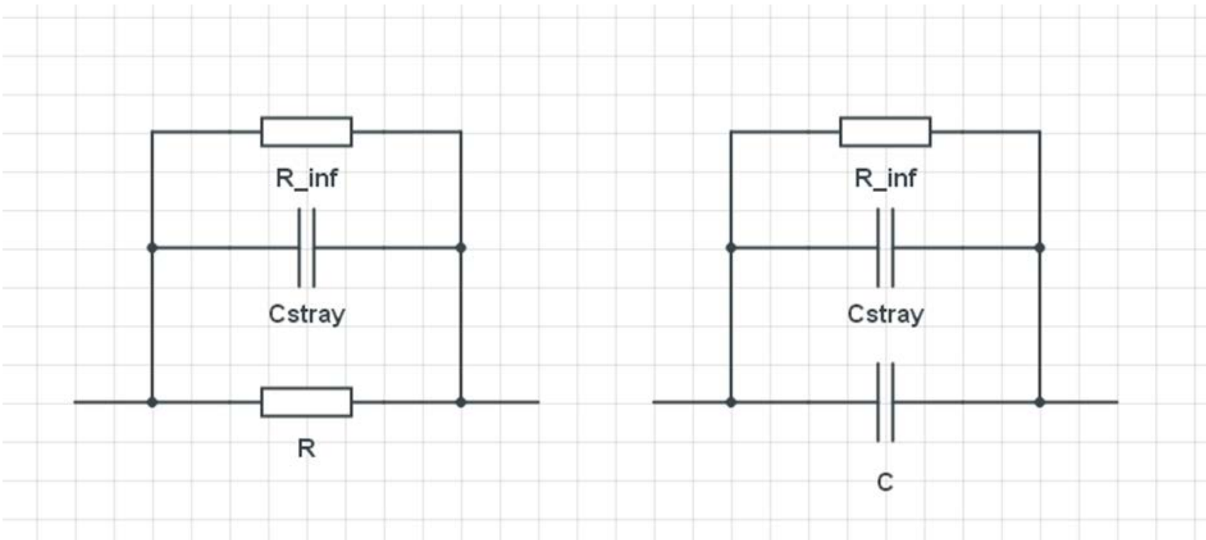


Figure 1 On the left is a generic resistive channel circuit (1-12), on the right the capacitive channel (13), with *R* and *C* denoting the nominal resistor and capacitor values, respectively, *R_inf* denoting the very large standing parallel resistance, and *Cstray* the stray capacitance.

For a given angular frequency, *ω*, the two circuits, respectively, will produce impedances Z_R and Z_C given by,

$$Z_R = \left[\left(\frac{1}{R_i} + \frac{1}{R_{inf}}\right) + j\omega C_{stray}\right]^{-1}$$

$$Z_C = \left[\frac{1}{R_{inf}} + j\omega\left(C_{13} + C_{stray}\right)\right]^{-1}$$

Where the nominal values of *R* and *C* have been replaced with actual values, subscripted with the number of the resistor box channel. In both cases the impedance may be reduced to a simple parallel *RC* circuit with one resistive and one capacitive element, the magnitude of which is given by,

$$|Z_{RC}| = \frac{R}{\sqrt{1 + \omega^2 R^2 C^2}}$$

and phase by,

$$\angle Z_{RC} = \tan^{-1}(-\omega RC)$$

Where the resistive channel has $R = (1/R_i + 1/R_\infty)^{-1}$ and $C = C_{stray}$, and the capacitive channel has $R = R_\infty$ and $C = C_{13} + C_{stray}$.

With reference to the standard reciprocity calibration system circuits, the voltage V_{2A} is measured across the series impedance Z_{RC} described above (resistive or capacitive) and may be used to find the current, *i*, through the impedance. V_{1A} is the voltage measured across the receiver microphone, and this may be used as a proxy for the output voltage from the impedance, *U*. A set of measurements of V_{1A} and V_{2A} are made on the reciprocity system at various frequencies, for example, by running a single microphone pair measurement. Two runs are required, one in a resistive channel (1-12) and one in the capacitive channel (13). *U/i* is determined for each channel at each frequency from the measured voltages. Correct values for resistance are known from annual calibrations (a direct measurement), and stray capacitance may be relatively accurately estimated (see separate section below). From the well-known reciprocity relationship for microphone sensitivity produce M_1M_2 we get:

$$M_1 M_2\, Z_a = \frac{U}{i} = Z_C \frac{U_C}{V_C} = Z_R \frac{U_R}{V_R}$$

If the same coupler and microphones are used for both measurements then the quantity on the left hand side is constant for each frequency. The equality on the right hand side of this equation and the previous expressions for Z_C and Z_R allow the unknown *C* to be related to measured quantities for a given frequency. It is not possible (or at least not straightforward) to analytically solve for C_{13}, but it is convenient to arrive at a value for $C = C_{13} + C_{stray}$ by solving the preceding equality by a numerical method.

Determination of total channel capacitance using this method includes the capacitor as well as the stray capacitance, which is necessarily assumed to be the same as in the resistive channel. There is some uncertainty associated with the separate method for determining stray capacitance (detailed in the section below), but because only the total capacitance is desired for channel 13, the stray capacitance uncertainty may be excluded from the uncertainty evaluation.

1.1 Uncertainty

The capacitance calibration affects the microphone sensitivity through its influence on the voltage measured by the lock-in amp. The uncertainty in microphone sensitivity due to capacitance calibration is calculated from the corresponding type A and type B components in a frequency region where the resistor accuracy is proven and with trusted microphones. All type B uncertainties cancel due to the repeated measurements with the exception of the resistor calibration component. Type A uncertainty prevails for both resistance and capacitance measurements, and is thus considered twice.

To determine the uncertainty in C by this method it is necessary to transform from uncertainty in microphone sensitivity (dB) for which the components above are in terms of, to the corresponding uncertainty in current, to uncertainty in reactance, and finally to an uncertainty in the value of C itself. This is straight forwardly (if tediously) achieved in a spreadsheet using the standard relationship for capacitive reactance and the reciprocity equation.

Once an uncertainty on C has been determined by this method for one or more frequencies, the value may finally be used in the frequency dependent expression for complex impedance to derive the level and phase uncertainty in microphone sensitivity due to capacitor calibration. This factor is assumed to have a rectangular probability distribution.

Capacitor Magnitude

Source of uncertainty	**Contribution to overall uncertainty (dB)**	**Distribution**
Calibration of resistors in resistor box	0.0005	Rectangular
Repeatability of reciprocity measurement with LS1 at 100 Hz via resistor R12	0.01	Normal
Temperature dependence of C (Assumed; 20.5 C to 24.5 C)	0.005	Rectangular
Drift based on largest difference between consecutive annual meausurements of the capacitor (estimated)	0.005	Rectangular
Repeatability of measurement of C (+/- 0.01 nF)	0.01	Normal
Slope of R vs C over the range 1 Hz to 20 Hz	0.01	Rectangular
Total	0.0158	Normal
Quantity allowed for in overall uncertainty calculation	0.0274	Rectangular

Determine dC by back-calculation 2.98E-11 F

Nominal C = 4.7e-9 F, so dC/C = 6340 ppm

Capacitor Phase

Source of uncertainty	Contribution to overall uncertainty (degrees)	Distribution
Uncertainty in C as determined by Magnitude method (6340 ppm) is 2.98E-11 F	Frequency dependent	Rectangular
Error seen in R vs C measurement over range 1 Hz to 20 Hz	0.05	Rectangular
Total	Frequency dependent	

2 Determination of stray capacitance

Stray capacitance describes the total capacitance in each channel due to all components other than capacitors. In practice it primarily arises from wiring, switches, relays, and cabling. It makes a non-negligible contribution to the impedance of each channel, particularly in phase, where a non-zero capacitance can cause a significant phase shift.

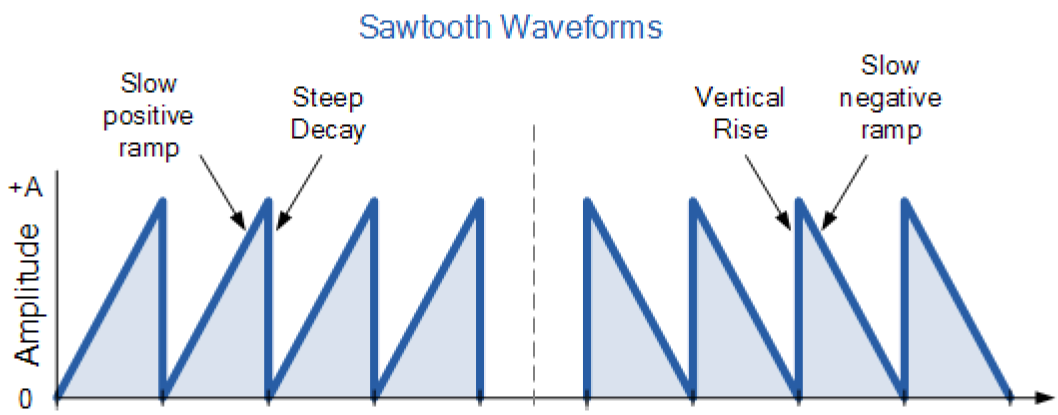
For the sake of its determination, the stray capacitance is assumed to be broadly the same across all the channels and in parallel with the resistors. The resistance changes by channel, and therefore there are 13 RC circuits to consider, one for each channel. Furthermore, reactance changes with frequency, leading to non-constant impedance within the frequency range of each channel. If stray capacitance is not corrected for, this multiple resistance arrangement will lead to a saw-toothing of the microphone sensitivity curve, especially in phase.

2.1 Stray Capacitance

The response of a measurement microphone is known from physical considerations to be free from discontinuities, and its measured response is expected to be a smooth function of frequency. As there is no direct measurement of stray capacitance available, it is determined through an optimisation process, where the stray capacitance value accepted is that which provides the smoothest microphone sensitivity product.

1. As for the previous section, two microphone pair measurements are made in the reciprocity system, one using channel 13 (capacitor channel) for all frequencies and the other stepping through channels 1 to 12 (resistors) with frequency.
2. A spreadsheet may be constructed wherein: Z_a is as calculated by the software; U_R, U_C, V_R, and V_C are as measured; and Z_R and Z_C are calculated from the known values of resistance and/or capacitance for each channel, and stray capacitance is left as a variable. The sensitivity product is then calculated twice, once for the capacitive impedance measurement, and once for the resistive impedance measurement.
3. The difference between the two sensitivity product calculations is plotted, effectively normalising the resistive measurements, and allowing saw-toothing to be readily identified. For this purpose the more sensitive phase response is preferred.
4. Through iteration, a value for stray capacitance is identified that minimises the amount of saw-toothing present. Experience shows that a visual assessment is as accurate as a more objective

statistical measure such as the coefficient of determination, R^2. Note that the direction of the saw-toothing is inverted for a C_{stray} value that is too low compared with one that is too high. It will not be possible to achieve a perfectly smooth curve due to measurement error in the underlying data and small variations in the value of C_{stray} between channels. This is an area where a visual assessment has an advantage over purely statistical methods, because it allows for scientific judgement to benefit the fitting process.



2.2 Uncertainty

The uncertainty in the value obtained in 2.1 is assessed to be the half the range of the possible values for C_{stray}. The minimum possible value is reasonably determined as the highest capacitance below the best estimate of C_{stray} for which all the saw-toothing in the curve is in the same direction (either a positive or a negative slope). Similarly the maximum possible value is the lowest capacitance above the estimate of C_{stray} for which all the saw-toothing is in the opposite direction.

Whereas stray capacitance uncertainty by this method is a constant, its effect on the microphone sensitivity uncertainty is dependent on frequency and channel (because of the varying resistances). To determine the effect of this component on microphone sensitivity, at each frequency the equivalent RC circuit must be constructed.

The uncertainty in microphone sensitivity due to uncertainty in C_{stray} is determined as the change produced due to incrementing C_{stray} by its uncertainty, all else held constant. This factor is assumed to have a rectangular probability distribution.

B.3 NMISA

The open-circuit pressure and phase sensitivities of the microphone were determined by the pressure reciprocity technique as described in IEC 61094-2: 2009. A Brüel & Kjær 9699 calibration system, comprising of a 5998 reciprocity calibration apparatus with low frequency modification WH-3432 and a Pulse front-end 3560-C, was used in measuring the voltage ratios. The Pulse software was setup to utilise it in the SSR mode with an accuracy setting of 0,001 dB and with generator levels of 2 V and 3 V, the latter being for the low frequency range to improve signal-to-noise levels. Grounded guard configurations were used for the transmitter unit, Brüel & Kjær ZE-0796-W-001, and the two preamplifiers, Brüel & Kjær 2673-W-003 and 2673-W-004. The microphone measurement pairings were placed inside a chamber that attenuates environmental noise and which was pressurised to the nominal reference static pressure. Additionally, the chamber was placed on a static vibration isolation table.

The environmental parameters were measured using a Rotronics Hygroclip probe placed inside the chamber and a Druck DPI141 barometer that measured the static pressure inside the chamber. The microphone's modulus and phase pressure- and temperature coefficients were determined based on the technique as described by: K. Rasmussen, "The static pressure and temperature coefficients of laboratory standard microphones," Metrologia, 1999, 36, pp. 265 – 273; K. Rasmussen, "The influence of environmental conditions on the pressure sensitivity of measurement microphones", Brüel and Kjær Technical Review No. 1 2001.

The broad-band solution, as described in IEC 61094-2: 2009, was applied in correcting for heat conduction effects together with corrections made for radial wave motion. Four air filled sapphire plane-wave couplers of nominal lengths 4,3 mm, 5,7 mm, 7,5 mm and 15 mm were used. The two couplers with the longest nominal lengths were used at the lowest frequencies and the two couplers with the shortest nominal lengths were used at the highest frequencies. The results were calculated with the Mp.exe V4.0 software.

The front volume, equivalent volume, resonant frequency and loss factor were determined by employing analytical calculations, using the four plane-wave couplers.

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

B.4 VTT MIKES

Description of the method and instrumentation in MIKES

The calibrations were performed according to IEC 61094-2:2009. Two couplers with capillary tubes were used; one planewave type and one large volume type. No additional sealing (e.g. grease) was used between microphones and couplers.

Dimensional quantities of the couplers and microphones were measured by the MIKES length laboratory.

The measurement hardware (excluding the microphone preamplifiers) and software for performing the measurements and analysing the measurement results are developed in MIKES.

A National Instruments PXI-system with a 24-bit AD/DA converter was used for signal generation and simultaneous two channel voltage measurements. A software based lock-in-amplifier was used to achieve a narrow bandwidth measurement.

The current trough the transmitting microphone is measured with a reference capacitance connected in series with the transmitting microphone. The open circuit voltage of the receiver microphone is measured by the insert voltage technique.

Deviations from the standard

None declared.

Declared parameters

The front cavity depth and diameter of the diaphragm were measured in MIKES length laboratory, by using an optical method. The resonance frequency, front volume, equivalent volume and loss factor were obtained from the data optimization analysis of the measurements results with different sized couplers.

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

Calculations

The calculations are done according to IEC 61094-2:2009. The individual microphone sensitivities are obtained by an iterative method. Microphone parameters are obtained by a fitting algorithm.

The uncertainty calculation is based on parameter variation and was done according to publication Evaluation of measurement data – Guide to the expression of uncertainty in measurement (JCGM 100:2008).

ANNEX C – PARTICIPANT REPORTED RESULTS

C.1 CMI

Artefact	4160 s/n: 811014				4160 s/n: 2036126			
Frequency (Hz)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)
1.995								
2.512								
3.162								
3.981								
5.012								
6.310								
7.943								
10.000								
12.589								
15.849								
19.953	-26.138	0.085			-27.364	0.085		
21.135	-26.145	0.085			-27.368	0.085		
22.387	-26.150	0.084			-27.374	0.084		
23.714	-26.159	0.065			-27.380	0.065		
25.119	-26.164	0.065			-27.382	0.065		
26.607	-26.170	0.065			-27.388	0.065		
28.184	-26.176	0.065			-27.390	0.065		
29.854	-26.181	0.065			-27.394	0.065		
31.623	-26.187	0.055			-27.404	0.055		
33.497	-26.192	0.055			-27.404	0.055		
35.481	-26.196	0.055			-27.410	0.055		
37.584	-26.202	0.055			-27.412	0.055		
39.811	-26.206	0.055			-27.417	0.055		
42.170	-26.211	0.055			-27.420	0.055		
44.668	-26.214	0.055			-27.423	0.055		
47.315	-26.218	0.055			-27.428	0.055		
50.119	-26.223	0.055			-27.426	0.055		
53.088	-26.226	0.055			-27.430	0.055		
56.234	-26.230	0.045			-27.436	0.045		
59.566	-26.234	0.045			-27.437	0.045		
63.096	-26.238	0.045			-27.441	0.045		
66.834	-26.240	0.045			-27.445	0.045		
70.795	-26.244	0.045			-27.445	0.045		
74.989	-26.247	0.045			-27.448	0.045		
79.433	-26.251	0.045			-27.451	0.045		
84.140	-26.254	0.045			-27.455	0.045		
89.125	-26.256	0.037			-27.457	0.037		
94.406	-26.260	0.037			-27.457	0.037		
100.00	-26.262	0.037			-27.460	0.037		
105.93	-26.265	0.037			-27.464	0.037		
112.20	-26.268	0.037			-27.466	0.037		
118.85	-26.270	0.037			-27.468	0.037		
125.89	-26.273	0.037			-27.470	0.037		
133.35	-26.276	0.037			-27.471	0.037		
141.25	-26.278	0.037			-27.474	0.037		
149.62	-26.280	0.037			-27.475	0.037		
158.49	-26.282	0.037			-27.477	0.037		
167.88	-26.284	0.037			-27.479	0.037		
177.83	-26.285	0.037			-27.484	0.037		
188.36	-26.287	0.037			-27.479	0.037		
199.53	-26.289	0.037			-27.481	0.037		
211.35	-26.291	0.037			-27.482	0.037		
223.87	-26.292	0.037			-27.481	0.037		
237.14	-26.294	0.037			-27.483	0.037		
251.19	-26.295	0.037			-27.485	0.037		
266.07	-26.296	0.037			-27.485	0.037		
281.84	-26.298	0.037			-27.488	0.037		
298.54	-26.299	0.037			-27.485	0.037		
316.23	-26.299	0.037			-27.490	0.037		
334.97	-26.300	0.037			-27.487	0.037		
354.81	-26.301	0.037			-27.488	0.037		
375.84	-26.301	0.037			-27.490	0.037		
398.11	-26.301	0.037			-27.490	0.037		
421.70	-26.302	0.037			-27.488	0.037		
446.68	-26.302	0.037			-27.489	0.037		
473.15	-26.301	0.037			-27.489	0.037		
501.19	-26.301	0.037			-27.488	0.037		

530.88	-26.300	0.037				-27.489	0.037			
562.34	-26.299	0.037				-27.488	0.037			
595.66	-26.297	0.037				-27.487	0.037			
630.96	-26.295	0.037				-27.487	0.037			
668.34	-26.293	0.037				-27.485	0.037			
707.95	-26.290	0.037				-27.480	0.037			
749.89	-26.287	0.037				-27.480	0.037			
794.33	-26.284	0.037				-27.476	0.037			
841.40	-26.280	0.037				-27.473	0.037			
891.25	-26.275	0.036				-27.472	0.036			
944.06	-26.270	0.036				-27.465	0.036			
1 000.0	-26.263	0.036				-27.460	0.036			
1 059.3	-26.256	0.036				-27.455	0.036			
1 122.0	-26.248	0.036				-27.450	0.036			
1 188.5	-26.240	0.036				-27.441	0.036			
1 258.9	-26.229	0.036				-27.433	0.036			
1 333.5	-26.217	0.036				-27.426	0.036			
1 412.5	-26.204	0.036				-27.415	0.036			
1 496.2	-26.189	0.036				-27.405	0.036			
1 584.9	-26.174	0.036				-27.397	0.036			
1 678.8	-26.156	0.036				-27.384	0.036			
1 778.3	-26.134	0.036				-27.369	0.036			
1 883.6	-26.111	0.036				-27.350	0.036			
1 995.3	-26.085	0.036				-27.332	0.036			
2 113.5	-26.056	0.036				-27.309	0.036			
2 238.7	-26.023	0.037				-27.284	0.037			
2 371.4	-25.987	0.037				-27.259	0.037			
2 511.9	-25.948	0.037				-27.227	0.037			
2 660.7	-25.904	0.037				-27.195	0.037			
2 818.4	-25.856	0.037				-27.160	0.037			
2 985.4	-25.804	0.037				-27.119	0.037			
3 162.3	-25.747	0.037				-27.076	0.037			
3 349.7	-25.686	0.037				-27.030	0.037			
3 548.1	-25.621	0.037				-26.979	0.037			
3 758.4	-25.553	0.037				-26.925	0.037			
3 981.1	-25.483	0.037				-26.871	0.037			
4 217.0	-25.413	0.037				-26.814	0.037			
4 466.8	-25.346	0.037				-26.758	0.037			
4 731.5	-25.287	0.037				-26.703	0.037			
5 011.9	-25.239	0.037				-26.653	0.037			
5 308.8	-25.213	0.037				-26.615	0.037			
5 623.4	-25.221	0.037				-26.591	0.037			
5 956.6	-25.275	0.037				-26.594	0.037			
6 309.6	-25.398	0.046				-26.629	0.046			
6 683.4	-25.600	0.046				-26.715	0.046			
7 079.5	-25.901	0.055				-26.861	0.055			
7 498.9	-26.330	0.056				-27.090	0.056			
7 943.3	-26.893	0.066				-27.428	0.066			
8 414.0	-27.597	0.067				-27.880	0.067			
8 912.5	-28.446	0.086				-28.480	0.086			
9 440.6	-29.423	0.106				-29.179	0.106			
10 000.0	-30.502	0.145				-30.004	0.145			

C.2 NPL

Artefact	4160 s/n: 811014				4160 s/n: 2036126			
Frequency (Hz)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)
1.995	-25.216	0.250	175.25	3.30	-26.722	0.250	177.17	3.30
2.512	-25.418	0.250	175.65	3.30	-26.793	0.250	177.17	3.30
3.162	-25.547	0.250	175.87	3.30	-26.897	0.250	177.29	3.30
3.981	-25.636	0.070	176.17	1.50	-26.976	0.070	177.37	1.50
5.012	-25.740	0.070	176.49	1.50	-27.036	0.070	177.55	1.50
6.310	-25.822	0.070	176.59	1.50	-27.092	0.070	177.74	1.50
7.943	-25.904	0.060	176.93	0.80	-27.154	0.060	177.88	0.80
10.000	-25.965	0.060	177.23	0.80	-27.196	0.060	178.04	0.80
12.589	-26.019	0.060	177.49	0.80	-27.236	0.060	178.20	0.80
15.849	-26.065	0.050	177.73	0.50	-27.270	0.050	178.35	0.50
19.953	-26.102	0.030	178.00	0.50	-27.318	0.030	178.50	0.50
21.135	-26.107	0.030	178.04	0.50	-27.330	0.030	178.52	0.50
22.387	-26.114	0.030	178.09	0.50	-27.336	0.030	178.54	0.50
23.714	-26.122	0.030	178.13	0.50	-27.342	0.030	178.57	0.50
25.119	-26.134	0.030	178.17	0.40	-27.343	0.030	178.61	0.40
26.607	-26.138	0.030	178.20	0.40	-27.356	0.030	178.62	0.40
28.184	-26.146	0.030	178.24	0.40	-27.359	0.030	178.64	0.40
29.854	-26.154	0.030	178.27	0.40	-27.367	0.030	178.66	0.40
31.623	-26.161	0.030	178.30	0.40	-27.367	0.030	178.68	0.40
33.497	-26.166	0.030	178.33	0.40	-27.376	0.030	178.69	0.40
35.481	-26.173	0.030	178.37	0.40	-27.380	0.030	178.71	0.40
37.584	-26.177	0.030	178.39	0.40	-27.387	0.030	178.72	0.40
39.811	-26.184	0.030	178.41	0.40	-27.390	0.030	178.73	0.40
42.170	-26.189	0.030	178.43	0.40	-27.395	0.030	178.76	0.40
44.668	-26.194	0.030	178.45	0.40	-27.398	0.030	178.76	0.40
47.315	-26.198	0.030	178.47	0.40	-27.403	0.030	178.77	0.40
50.119	-26.205	0.030	178.48	0.40	-27.408	0.030	178.77	0.40
53.088	-26.211	0.030	178.49	0.40	-27.411	0.030	178.77	0.40
56.234	-26.212	0.030	178.50	0.40	-27.416	0.030	178.78	0.40
59.566	-26.220	0.030	178.51	0.40	-27.420	0.030	178.78	0.40
63.096	-26.225	0.030	178.51	0.40	-27.422	0.030	178.78	0.40
66.834	-26.227	0.030	178.51	0.40	-27.426	0.030	178.77	0.40
70.795	-26.233	0.030	178.52	0.40	-27.429	0.030	178.77	0.40
74.989	-26.238	0.030	178.51	0.40	-27.434	0.030	178.77	0.40
79.433	-26.242	0.030	178.49	0.40	-27.434	0.030	178.77	0.40
84.140	-26.245	0.030	178.51	0.40	-27.442	0.030	178.75	0.40
89.125	-26.248	0.030	178.49	0.40	-27.442	0.030	178.72	0.40
94.406	-26.252	0.030	178.50	0.40	-27.447	0.030	178.70	0.40
100.00	-26.257	0.030	178.49	0.40	-27.448	0.030	178.68	0.40
105.93	-26.257	0.030	178.46	0.40	-27.450	0.030	178.67	0.40
112.20	-26.261	0.030	178.43	0.40	-27.455	0.030	178.65	0.40
118.85	-26.266	0.030	178.40	0.40	-27.456	0.030	178.62	0.40
125.89	-26.269	0.030	178.37	0.40	-27.459	0.030	178.58	0.40
133.35	-26.271	0.030	178.33	0.40	-27.461	0.030	178.54	0.40
141.25	-26.274	0.030	178.30	0.40	-27.464	0.030	178.50	0.40
149.62	-26.277	0.030	178.25	0.40	-27.466	0.030	178.47	0.40
158.49	-26.281	0.030	178.20	0.40	-27.469	0.030	178.43	0.40
167.88	-26.283	0.030	178.16	0.40	-27.471	0.030	178.37	0.40
177.83	-26.286	0.030	178.12	0.40	-27.472	0.030	178.32	0.40
188.36	-26.287	0.030	178.05	0.40	-27.473	0.030	178.25	0.40
199.53	-26.290	0.030	177.98	0.40	-27.476	0.030	178.19	0.40
211.35	-26.293	0.030	177.91	0.40	-27.477	0.030	178.12	0.40
223.87	-26.292	0.030	177.83	0.40	-27.480	0.030	178.04	0.40
237.14	-26.296	0.030	177.75	0.40	-27.482	0.030	177.97	0.40
251.19	-26.299	0.030	177.67	0.40	-27.483	0.030	177.89	0.40
266.07	-26.300	0.030	177.56	0.40	-27.483	0.030	177.80	0.40
281.84	-26.300	0.030	177.47	0.40	-27.485	0.030	177.70	0.40
298.54	-26.303	0.030	177.35	0.40	-27.485	0.030	177.58	0.40
316.23	-26.303	0.030	177.25	0.40	-27.487	0.030	177.49	0.40
334.97	-26.305	0.030	177.11	0.40	-27.487	0.030	177.37	0.40
354.81	-26.305	0.030	177.01	0.40	-27.489	0.030	177.27	0.40
375.84	-26.305	0.030	176.87	0.40	-27.491	0.030	177.14	0.40
398.11	-26.306	0.030	176.75	0.40	-27.491	0.030	176.99	0.40
421.70	-26.307	0.030	176.57	0.40	-27.490	0.030	176.85	0.40
446.68	-26.307	0.030	176.38	0.40	-27.490	0.030	176.68	0.40
473.15	-26.310	0.030	176.22	0.40	-27.489	0.030	176.52	0.40
501.19	-26.306	0.030	176.00	0.40	-27.490	0.030	176.33	0.40

530.88	-26.307	0.030	175.81	0.50	-27.490	0.030	176.13	0.50
562.34	-26.306	0.030	175.59	0.50	-27.489	0.030	175.93	0.50
595.66	-26.306	0.030	175.36	0.50	-27.489	0.030	175.70	0.50
630.96	-26.305	0.030	175.11	0.50	-27.488	0.030	175.47	0.50
668.34	-26.301	0.030	174.85	0.50	-27.488	0.030	175.19	0.50
707.95	-26.301	0.030	174.56	0.50	-27.485	0.030	174.94	0.50
749.89	-26.296	0.030	174.27	0.50	-27.484	0.030	174.70	0.50
794.33	-26.294	0.030	173.94	0.50	-27.482	0.030	174.40	0.50
841.40	-26.290	0.030	173.60	0.50	-27.478	0.030	174.07	0.50
891.25	-26.285	0.030	173.24	0.50	-27.475	0.030	173.74	0.50
944.06	-26.281	0.030	172.90	0.50	-27.471	0.030	173.39	0.50
1 000.0	-26.275	0.030	172.52	0.50	-27.466	0.030	173.00	0.50
1 059.3	-26.266	0.030	172.05	0.60	-27.464	0.030	172.58	0.60
1 122.0	-26.260	0.030	171.59	0.60	-27.456	0.030	172.15	0.60
1 188.5	-26.249	0.030	171.05	0.60	-27.448	0.030	171.74	0.60
1 258.9	-26.240	0.030	170.55	0.60	-27.440	0.030	171.23	0.60
1 333.5	-26.226	0.030	169.96	0.60	-27.431	0.030	170.70	0.60
1 412.5	-26.216	0.030	169.39	0.60	-27.422	0.030	170.15	0.60
1 496.2	-26.200	0.030	168.73	0.60	-27.412	0.030	169.59	0.60
1 584.9	-26.183	0.030	168.06	0.60	-27.397	0.030	168.93	0.60
1 678.8	-26.164	0.030	167.34	0.60	-27.385	0.030	168.30	0.60
1 778.3	-26.142	0.030	166.50	0.60	-27.367	0.030	167.52	0.60
1 883.6	-26.119	0.030	165.69	0.60	-27.349	0.030	166.78	0.60
1 995.3	-26.093	0.030	164.79	0.60	-27.330	0.030	165.96	0.60
2 113.5	-26.063	0.030	163.83	0.60	-27.308	0.030	165.08	0.60
2 238.7	-26.032	0.030	162.78	0.60	-27.283	0.030	164.14	0.60
2 371.4	-25.995	0.030	161.64	0.60	-27.256	0.030	163.17	0.60
2 511.9	-25.958	0.030	160.46	0.60	-27.226	0.030	162.05	0.60
2 660.7	-25.913	0.040	159.16	0.70	-27.195	0.040	160.89	0.70
2 818.4	-25.864	0.040	157.67	0.70	-27.157	0.040	159.58	0.70
2 985.4	-25.812	0.040	156.10	0.70	-27.116	0.040	158.17	0.70
3 162.3	-25.757	0.040	154.47	0.70	-27.074	0.040	156.73	0.70
3 349.7	-25.696	0.040	152.59	0.70	-27.027	0.040	155.09	0.70
3 548.1	-25.630	0.040	150.54	0.70	-26.975	0.040	153.33	0.70
3 758.4	-25.563	0.040	148.31	0.70	-26.922	0.040	151.39	0.70
3 981.1	-25.493	0.040	145.86	0.70	-26.867	0.040	149.31	0.70
4 217.0	-25.422	0.050	143.09	0.70	-26.808	0.050	146.96	0.70
4 466.8	-25.357	0.050	140.06	0.70	-26.750	0.050	144.45	0.70
4 731.5	-25.299	0.050	136.80	0.70	-26.694	0.050	141.73	0.70
5 011.9	-25.251	0.050	133.08	0.70	-26.645	0.050	138.64	0.70
5 308.8	-25.228	0.050	128.90	0.70	-26.604	0.050	135.21	0.70
5 623.4	-25.234	0.050	124.40	0.70	-26.581	0.050	131.46	0.70
5 956.6	-25.287	0.050	119.31	0.70	-26.579	0.050	127.17	0.70
6 309.6	-25.404	0.050	113.84	0.60	-26.613	0.050	122.61	0.60
6 683.4	-25.598	0.060	107.97	0.60	-26.694	0.060	117.60	0.60
7 079.5	-25.898	0.060	101.59	0.60	-26.838	0.060	112.05	0.60
7 498.9	-26.322	0.060	95.02	0.60	-27.065	0.060	106.14	0.60
7 943.3	-26.857	0.060	88.46	0.50	-27.398	0.060	99.93	0.50
8 414.0	-27.545	0.110	81.91	0.80	-27.850	0.110	93.48	0.80
8 912.5	-28.367	0.110	75.63	0.80	-28.442	0.110	86.96	0.80
9 440.6	-29.312	0.110	69.77	0.80	-29.138	0.110	80.70	0.80
10 000.0	-30.366	0.110	64.47	0.80	-29.967	0.110	74.23	0.80

C.3 NMISA

Artefact	4160 s/n: 811014				4160 s/n: 2036126			
Frequency (Hz)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)
1.995	-25.236	0.075	174.37	0.20	-26.707	0.075	175.64	0.20
2.512	-25.382	0.070	174.67	0.20	-26.814	0.070	175.95	0.20
3.162	-25.513	0.060	175.02	0.15	-26.906	0.060	176.26	0.15
3.981	-25.629	0.055	175.40	0.15	-26.987	0.055	176.57	0.15
5.012	-25.732	0.050	175.80	0.10	-27.060	0.050	176.88	0.10
6.310	-25.821	0.050	176.20	0.10	-27.123	0.050	177.17	0.10
7.943	-25.898	0.045	176.60	0.08	-27.178	0.045	177.46	0.08
10.000	-25.962	0.040	176.97	0.08	-27.225	0.040	177.72	0.08
12.589	-26.015	0.040	177.30	0.07	-27.264	0.040	177.96	0.07
15.849	-26.059	0.035	177.59	0.07	-27.298	0.035	178.16	0.07
19.953	-26.098	0.035	177.83	0.07	-27.327	0.035	178.32	0.07
21.135	-26.106	0.035	177.88	0.07	-27.334	0.035	178.36	0.07
22.387	-26.114	0.035	177.94	0.07	-27.340	0.035	178.40	0.07
23.714	-26.123	0.035	177.99	0.07	-27.347	0.035	178.43	0.07
25.119	-26.131	0.030	178.04	0.07	-27.353	0.030	178.47	0.07
26.607	-26.138	0.030	178.09	0.07	-27.358	0.030	178.50	0.07
28.184	-26.145	0.030	178.13	0.07	-27.364	0.030	178.53	0.07
29.854	-26.152	0.030	178.17	0.07	-27.370	0.030	178.55	0.07
31.623	-26.158	0.030	178.21	0.07	-27.375	0.030	178.58	0.07
33.497	-26.165	0.030	178.24	0.07	-27.380	0.030	178.60	0.07
35.481	-26.171	0.030	178.28	0.07	-27.385	0.030	178.62	0.07
37.584	-26.177	0.030	178.31	0.07	-27.390	0.030	178.64	0.07
39.811	-26.183	0.030	178.33	0.07	-27.395	0.030	178.66	0.07
42.170	-26.188	0.030	178.36	0.07	-27.399	0.030	178.68	0.07
44.668	-26.194	0.030	178.38	0.07	-27.404	0.030	178.69	0.07
47.315	-26.199	0.030	178.40	0.07	-27.408	0.030	178.70	0.07
50.119	-26.204	0.030	178.42	0.07	-27.412	0.030	178.71	0.07
53.088	-26.209	0.030	178.44	0.07	-27.416	0.030	178.72	0.07
56.234	-26.214	0.030	178.45	0.07	-27.420	0.030	178.73	0.07
59.566	-26.218	0.030	178.46	0.07	-27.424	0.030	178.73	0.07
63.096	-26.223	0.030	178.47	0.07	-27.427	0.030	178.73	0.07
66.834	-26.227	0.030	178.48	0.07	-27.431	0.030	178.73	0.07
70.795	-26.232	0.030	178.48	0.07	-27.435	0.030	178.73	0.07
74.989	-26.236	0.030	178.48	0.07	-27.438	0.030	178.72	0.07
79.433	-26.240	0.030	178.48	0.07	-27.441	0.030	178.72	0.07
84.140	-26.244	0.030	178.47	0.07	-27.445	0.030	178.71	0.07
89.125	-26.247	0.030	178.46	0.07	-27.448	0.030	178.70	0.07
94.406	-26.251	0.030	178.45	0.07	-27.451	0.030	178.68	0.07
100.000	-26.254	0.030	178.42	0.07	-27.453	0.030	178.65	0.07
105.925	-26.258	0.030	178.41	0.07	-27.456	0.030	178.63	0.07
112.202	-26.261	0.030	178.39	0.07	-27.459	0.030	178.61	0.07
118.850	-26.265	0.030	178.36	0.07	-27.462	0.030	178.58	0.07
125.893	-26.268	0.025	178.34	0.07	-27.464	0.025	178.56	0.07
133.352	-26.271	0.025	178.31	0.07	-27.467	0.025	178.52	0.07
141.254	-26.273	0.025	178.27	0.07	-27.469	0.025	178.49	0.07
149.624	-26.277	0.025	178.23	0.07	-27.471	0.025	178.45	0.07
158.489	-26.279	0.025	178.19	0.07	-27.473	0.025	178.41	0.07
167.880	-26.282	0.025	178.14	0.07	-27.476	0.025	178.36	0.07
177.828	-26.284	0.025	178.09	0.07	-27.478	0.025	178.31	0.07
188.365	-26.287	0.025	178.03	0.07	-27.480	0.025	178.26	0.07
199.526	-26.289	0.025	177.97	0.07	-27.482	0.025	178.20	0.07
211.349	-26.291	0.025	177.91	0.07	-27.483	0.025	178.13	0.07
223.872	-26.293	0.025	177.83	0.07	-27.485	0.025	178.06	0.07
237.137	-26.295	0.025	177.75	0.07	-27.487	0.025	177.99	0.07
251.189	-26.297	0.025	177.67	0.07	-27.488	0.025	177.91	0.07
266.073	-26.298	0.025	177.58	0.07	-27.489	0.025	177.82	0.07
281.838	-26.300	0.025	177.48	0.07	-27.491	0.025	177.73	0.07
298.538	-26.301	0.025	177.38	0.07	-27.492	0.025	177.63	0.07
316.228	-26.303	0.025	177.26	0.07	-27.493	0.025	177.52	0.07
334.965	-26.304	0.025	177.14	0.07	-27.494	0.025	177.41	0.07
354.813	-26.305	0.025	177.01	0.07	-27.495	0.025	177.29	0.07
375.837	-26.306	0.025	176.88	0.07	-27.496	0.025	177.16	0.07
398.107	-26.306	0.025	176.73	0.07	-27.496	0.025	177.02	0.07
421.697	-26.307	0.025	176.57	0.07	-27.496	0.025	176.87	0.07
446.684	-26.307	0.025	176.40	0.07	-27.497	0.025	176.71	0.07
473.151	-26.307	0.025	176.22	0.07	-27.497	0.025	176.55	0.07
501.187	-26.307	0.025	176.03	0.07	-27.497	0.025	176.37	0.07

530.884	-26.306	0.025	175.83	0.07	-27.496	0.025	176.18	0.07
562.341	-26.305	0.025	175.61	0.07	-27.496	0.025	175.98	0.07
595.662	-26.304	0.025	175.38	0.07	-27.495	0.025	175.76	0.07
630.957	-26.303	0.025	175.14	0.07	-27.494	0.025	175.53	0.07
668.344	-26.301	0.025	174.88	0.07	-27.492	0.025	175.29	0.07
707.946	-26.299	0.025	174.60	0.07	-27.491	0.025	175.03	0.07
749.894	-26.296	0.025	174.30	0.07	-27.489	0.025	174.75	0.07
794.328	-26.292	0.025	173.99	0.10	-27.486	0.025	174.46	0.10
841.395	-26.289	0.025	173.65	0.10	-27.483	0.025	174.15	0.10
891.251	-26.284	0.025	173.29	0.10	-27.480	0.025	173.82	0.10
944.061	-26.279	0.025	172.91	0.10	-27.476	0.025	173.47	0.10
1000.000	-26.273	0.025	172.51	0.10	-27.471	0.025	173.09	0.10
1059.254	-26.266	0.025	172.07	0.10	-27.465	0.025	172.69	0.10
1122.018	-26.257	0.025	171.62	0.10	-27.459	0.025	172.27	0.10
1188.502	-26.248	0.025	171.13	0.10	-27.452	0.025	171.82	0.10
1258.925	-26.238	0.025	170.60	0.15	-27.444	0.025	171.34	0.15
1333.521	-26.226	0.025	170.05	0.15	-27.435	0.025	170.82	0.15
1412.538	-26.213	0.025	169.45	0.15	-27.425	0.025	170.28	0.15
1496.236	-26.198	0.025	168.81	0.15	-27.414	0.025	169.69	0.15
1584.893	-26.181	0.030	168.13	0.15	-27.401	0.030	169.07	0.15
1678.804	-26.162	0.030	167.41	0.15	-27.386	0.030	168.41	0.15
1778.279	-26.141	0.030	166.63	0.15	-27.371	0.030	167.70	0.15
1883.649	-26.118	0.030	165.79	0.15	-27.352	0.030	166.94	0.15
1995.262	-26.091	0.035	164.90	0.15	-27.332	0.035	166.13	0.15
2113.489	-26.062	0.035	163.93	0.15	-27.310	0.035	165.26	0.15
2238.721	-26.029	0.035	162.90	0.15	-27.285	0.035	164.32	0.15
2371.374	-25.993	0.035	161.78	0.15	-27.257	0.035	163.32	0.15
2511.886	-25.953	0.040	160.57	0.20	-27.226	0.040	162.23	0.20
2660.725	-25.909	0.040	159.26	0.20	-27.191	0.040	161.07	0.20
2818.383	-25.860	0.040	157.83	0.20	-27.154	0.040	159.81	0.20
2985.383	-25.806	0.040	156.28	0.20	-27.113	0.040	158.45	0.20
3162.278	-25.749	0.045	154.59	0.20	-27.068	0.045	156.97	0.20
3349.654	-25.687	0.045	152.75	0.20	-27.020	0.045	155.36	0.20
3548.134	-25.621	0.045	150.72	0.20	-26.966	0.045	153.61	0.20
3758.374	-25.552	0.045	148.50	0.20	-26.911	0.045	151.69	0.20
3981.072	-25.480	0.045	146.04	0.20	-26.851	0.045	149.60	0.20
4216.965	-25.408	0.045	143.32	0.20	-26.791	0.045	147.29	0.20
4466.836	-25.340	0.045	140.30	0.20	-26.731	0.045	144.75	0.20
4731.513	-25.279	0.045	136.95	0.20	-26.672	0.045	141.96	0.20
5011.872	-25.231	0.050	133.22	0.30	-26.616	0.050	138.87	0.30
5308.844	-25.202	0.050	129.08	0.30	-26.571	0.050	135.44	0.30
5623.413	-25.208	0.050	124.48	0.30	-26.543	0.050	131.63	0.30
5956.621	-25.266	0.050	119.43	0.30	-26.543	0.050	127.44	0.30
6309.573	-25.381	0.060	113.91	0.40	-26.575	0.060	122.82	0.40
6683.439	-25.580	0.060	107.96	0.40	-26.657	0.060	117.75	0.40
7079.458	-25.881	0.060	101.65	0.40	-26.813	0.060	112.18	0.40
7498.942	-26.302	0.060	95.07	0.40	-27.047	0.060	106.25	0.40
7943.282	-26.857	0.075	88.38	0.55	-27.387	0.075	99.96	0.55
8413.951	-27.559	0.075	81.79	0.55	-27.854	0.075	93.51	0.55
8912.509	-28.396	0.075	75.53	0.55	-28.454	0.075	87.06	0.55
9440.609	-29.359	0.075	69.78	0.55	-29.158	0.075	80.83	0.55
10000.000	-30.441	0.090	64.58	0.70	-29.998	0.090	74.19	0.70

C.4 VTT MIKES

Artefact	4160 s/n: 811014				4160 s/n: 2036126			
Frequency (Hz)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)	Modulus (dB re 1 V/Pa)	Modulus *U* (dB)	Phase (°)	Phase *U* (°)
1.995								
2.512								
3.162								
3.981								
5.012								
6.310								
7.943								
10.000								
12.589								
15.849								
19.953	-26.122	0.055			-27.357	0.055		
21.135	-26.130	0.054			-27.362	0.054		
22.387	-26.139	0.053			-27.367	0.053		
23.714	-26.144	0.051			-27.374	0.051		
25.119	-26.149	0.050			-27.377	0.050		
26.607	-26.154	0.049			-27.379	0.049		
28.184	-26.162	0.048			-27.384	0.048		
29.854	-26.167	0.047			-27.389	0.047		
31.623	-26.173	0.047			-27.393	0.047		
33.497	-26.178	0.045			-27.397	0.045		
35.481	-26.183	0.044			-27.401	0.044		
37.584	-26.189	0.043			-27.405	0.043		
39.811	-26.193	0.042			-27.408	0.042		
42.170	-26.198	0.043			-27.412	0.043		
44.668	-26.202	0.042			-27.418	0.042		
47.315	-26.207	0.042			-27.417	0.042		
50.119	-26.211	0.042			-27.422	0.042		
53.088	-26.215	0.040			-27.425	0.040		
56.234	-26.219	0.039			-27.428	0.039		
59.566	-26.223	0.039			-27.431	0.039		
63.096	-26.226	0.039			-27.434	0.039		
66.834	-26.230	0.039			-27.437	0.039		
70.795	-26.234	0.038			-27.44	0.038		
74.989	-26.237	0.037			-27.443	0.037		
79.433	-26.241	0.036			-27.445	0.036		
84.140	-26.244	0.036			-27.448	0.036		
89.125	-26.247	0.037			-27.45	0.037		
94.406	-26.251	0.037			-27.453	0.037		
100.00	-26.253	0.037			-27.455	0.037		
105.93	-26.257	0.035			-27.457	0.035		
112.20	-26.258	0.035			-27.46	0.035		
118.85	-26.261	0.035			-27.462	0.035		
125.89	-26.265	0.035			-27.464	0.035		
133.35	-26.267	0.035			-27.466	0.035		
141.25	-26.270	0.035			-27.469	0.035		
149.62	-26.271	0.036			-27.47	0.036		
158.49	-26.275	0.034			-27.472	0.034		
167.88	-26.277	0.035			-27.475	0.035		
177.83	-26.279	0.035			-27.475	0.035		
188.36	-26.281	0.035			-27.477	0.035		
199.53	-26.285	0.036			-27.479	0.036		
211.35	-26.285	0.034			-27.479	0.034		
223.87	-26.284	0.034			-27.48	0.034		
237.14	-26.287	0.034			-27.482	0.034		
251.19	-26.289	0.034			-27.483	0.034		
266.07	-26.291	0.035			-27.485	0.035		
281.84	-26.292	0.034			-27.487	0.034		
298.54	-26.294	0.034			-27.487	0.034		
316.23	-26.295	0.034			-27.489	0.034		
334.97	-26.295	0.034			-27.49	0.034		
354.81	-26.296	0.034			-27.488	0.034		
375.84	-26.297	0.034			-27.488	0.034		
398.11	-26.296	0.034			-27.488	0.034		
421.70	-26.296	0.034			-27.489	0.034		
446.68	-26.297	0.034			-27.49	0.034		
473.15	-26.296	0.034			-27.49	0.034		
501.19	-26.296	0.034			-27.489	0.034		

530.88	-26.296	0.034					-27.489	0.034			
562.34	-26.295	0.034					-27.489	0.034			
595.66	-26.295	0.034					-27.487	0.034			
630.96	-26.294	0.034					-27.487	0.034			
668.34	-26.292	0.034					-27.485	0.034			
707.95	-26.289	0.035					-27.483	0.035			
749.89	-26.286	0.035					-27.481	0.035			
794.33	-26.287	0.036					-27.483	0.036			
841.40	-26.284	0.036					-27.48	0.036			
891.25	-26.279	0.036					-27.477	0.036			
944.06	-26.273	0.036					-27.473	0.036			
1 000.0	-26.267	0.037					-27.468	0.037			
1 059.3	-26.260	0.037					-27.463	0.037			
1 122.0	-26.252	0.037					-27.456	0.037			
1 188.5	-26.243	0.037					-27.45	0.037			
1 258.9	-26.234	0.037					-27.443	0.037			
1 333.5	-26.220	0.037					-27.433	0.037			
1 412.5	-26.207	0.037					-27.423	0.037			
1 496.2	-26.192	0.038					-27.412	0.038			
1 584.9	-26.176	0.038					-27.399	0.038			
1 678.8	-26.157	0.038					-27.384	0.038			
1 778.3	-26.136	0.038					-27.369	0.038			
1 883.6	-26.112	0.039					-27.351	0.039			
1 995.3	-26.087	0.039					-27.331	0.039			
2 113.5	-26.057	0.039					-27.309	0.039			
2 238.7	-26.023	0.040					-27.284	0.040			
2 371.4	-25.988	0.040					-27.259	0.040			
2 511.9	-25.948	0.041					-27.229	0.041			
2 660.7	-25.904	0.041					-27.193	0.041			
2 818.4	-25.856	0.042					-27.157	0.042			
2 985.4	-25.804	0.042					-27.117	0.042			
3 162.3	-25.746	0.043					-27.074	0.043			
3 349.7	-25.686	0.044					-27.026	0.044			
3 548.1	-25.623	0.044					-26.975	0.044			
3 758.4	-25.555	0.045					-26.922	0.045			
3 981.1	-25.483	0.046					-26.865	0.046			
4 217.0	-25.413	0.047					-26.807	0.047			
4 466.8	-25.348	0.049					-26.749	0.049			
4 731.5	-25.290	0.050					-26.693	0.050			
5 011.9	-25.245	0.052					-26.643	0.052			
5 308.8	-25.221	0.053					-26.602	0.053			
5 623.4	-25.229	0.055					-26.576	0.055			
5 956.6	-25.283	0.057					-26.577	0.057			
6 309.6	-25.402	0.060					-26.612	0.060			
6 683.4	-25.599	0.062					-26.696	0.062			
7 079.5	-25.896	0.065					-26.844	0.065			
7 498.9	-26.310	0.068					-27.075	0.068			
7 943.3	-26.856	0.071					-27.41	0.071			
8 414.0	-27.541	0.076					-27.861	0.076			
8 912.5	-28.377	0.080					-28.461	0.080			
9 440.6	-29.303	0.086					-29.161	0.086			
10 000.0	-30.339	0.094					-29.995	0.094			

ANNEX D – PARTICIPANT UNCERTAINTIES

D.1 CMI

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	19.95	21.13	22.39	23.71	25.12	26.61	28.18	29.85	31.62	33.50	35.48	37.58	39.81	42.17	44.67	47.32	50.12
Voltage ratio correction	CorR,n	dB	0.0017	0.0023	0.0022	0.0020	0.0020	0.0019	0.0019	0.0019	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	0.0093	0.0086	0.0079	0.0073	0.0068	0.0063	0.0058	0.0053	0.0049	0.0046	0.0042	0.0039	0.0036	0.0033	0.0031	0.0029	0.0026
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Temperature correction	CT	°C	0.100	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0028	0.0027	0.0026	0.0025	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0400	0.0400	0.0400	0.0300	0.0300	0.0300	0.0300	0.0300	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.043	0.042	0.042	0.033	0.033	0.032	0.032	0.032	0.028	0.028	0.028	0.027	0.027	0.027	0.027	0.027	0.027
Expanded uncertainty (k=2, U95%)				0.085	0.085	0.084	0.065	0.065	0.065	0.065	0.065	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Rounded uncertainty				**0.09**	**0.08**	**0.08**	**0.07**	**0.07**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	53.09	56.23	59.57	63.10	66.83	70.79	74.99	79.43	84.14	89.13	94.41	100.00	105.93	112.20	118.85	125.89	133.35
Voltage ratio correction	CorR,n	dB	0.0017	0.0018	0.0018	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	0.0024	0.0023	0.0021	0.0019	0.0018	0.0016	0.0015	0.0014	0.0013	0.0012	0.0011	0.0010	0.0009	0.0009	0.0008	0.0007	0.0007
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Temperature correction	CT	°C	0.100	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0021	0.0020	0.0020	0.0019	0.0018	0.0018	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014	0.0013	0.0013
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0250	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.027	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Expanded uncertainty (k=2, U95%)				0.055	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Rounded uncertainty				**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	141.25	149.62	158.49	167.88	177.83	188.36	199.53	211.35	223.87	237.14	251.19	266.07	281.84	298.54	316.23	334.97	354.81
Voltage ratio correction	CorR,n	dB	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	0.0006	0.0006	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Temperature correction	CT	°C	0.100	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0013	0.0012	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Expanded uncertainty (k=2, U95%)				0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Rounded uncertainty				**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	375.84	398.11	421.70	446.68	473.15	501.19	530.88	562.34	595.66	630.96	668.34	707.95	749.89	794.33	841.40	891.25	944.06
Voltage ratio correction	CorR,n	dB	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	0.0002	0.0002	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	0.0000
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Temperature correction	CT	°C	0.100	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Expanded uncertainty (k=2, U95%)				0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.036	0.036
Rounded uncertainty				**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	1000.0	1059.3	1122.0	1188.5	1258.9	1333.5	1412.5	1496.2	1584.9	1678.8	1778.3	1883.6	1995.3	2113.5	2238.7	2371.4	2511.9
Voltage ratio correction	CorR,n	dB	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	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
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Temperature correction	CT	°C	0.100	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Expanded uncertainty (k=2, U95%)				0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.037	0.037	0.037
Rounded uncertainty				**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	2660.7	2818.4	2985.4	3162.3	3349.7	3548.1	3758.4	3981.1	4217.0	4466.8	4731.5	5011.9	5308.8	5623.4	5956.6	6309.6	6683.4
Voltage ratio correction	CorR,n	dB	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
Coupler volume correction	CorCV	mm3	0.100	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	0.0001
Static Pressure Correction	CorPs	kPa	0.020	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
Capacitance correction	CorC	nF	0.01	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
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Temperature correction	CT	°C	0.100	0.0006	0.0006	0.0007	0.0008	0.0008	0.0009	0.0010	0.0011	0.0013	0.0014	0.0015	0.0016	0.0018	0.0019	0.0020	0.0021	0.0022
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0005	0.0006	0.0008	0.0011	0.0014	0.0020	0.0027	0.0037
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0200	0.0200
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.023	0.023
Expanded uncertainty (k=2, U95%)				0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.046	0.046
Rounded uncertainty				**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**

CMI - uncertainty budget for LS1P standard microphones

parameter	symbol	unit	uncrt./[Hz]	7079.5	7498.9	7943.3	8414.0	8912.5	9440.6	10000.0
Voltage ratio correction	CorR,n	dB	0.0017	0.0018	0.0018	0.0019	0.0019	0.0019	0.0020	0.0020
Coupler volume correction	CorCV	mm3	0.100	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Static Pressure Correction	CorPs	kPa	0.020	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
Capacitance correction	CorC	nF	0.01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Front volume correction	CorFV,n	mm3	5.35	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101	0.0101
Air pressure correction	CP	kPa	0.010	0.0004	0.0004	0.0004	0.0003	0.0003	0.0002	0.0001
Temperature correction	CT	°C	0.100	0.0022	0.0022	0.0022	0.0020	0.0018	0.0016	0.0013
Humidity correction	CRH	%	3	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Microphone Front cavity length	CL	mm	0.1	0.0049	0.0064	0.0081	0.0100	0.0121	0.0142	0.0162
Polarisation voltage	UPOL	V	0.01	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Repeatability	MP	dB	uA	0.0250	0.0250	0.0300	0.0300	0.0400	0.0500	0.0700
Total round	MP	dB	0.001	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Combined standard uncertainty				0.028	0.028	0.033	0.033	0.043	0.053	0.073
Expanded uncertainty (k=2, U95%)				0.055	0.056	0.066	0.067	0.086	0.106	0.145
Rounded uncertainty				**0.06**	**0.06**	**0.07**	**0.07**	**0.09**	**0.11**	**0.15**

D.2 NPL

	Valid for coupler UA1429								COMPONENTS OF TYPE B UNCERTAINTY EXPRESSED AS SEMI-RANGES (10^{-4} dB												
	SOURCE								Frequency (Hz)												
	Rectangular distribution applies unless stated	2	4	8	16	20	25	32	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
1	Resistor Box Accuracy - Resistance	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1	Resistor Box Accuracy - Capacitor	328	334	335	336	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	Stray Capacitance					30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
1	Non Linearity	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
2	Radius of Coupler	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	8	10	13
3	Velocity of Sound (dry air)	40	40	40	40	40	40	40	40	40	40	40	40	39	38	37	35	32	27	18	1
4	Ratio of Specific Heats	15	10	7	5	5	4	4	3	2	1	1	1	0	0	0	0	0	0	0	0
5	Ambient Pressure	13	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	13	12
6	Density of air	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	11	10
7	Length of Coupler	20	20	20	21	21	21	21	21	21	21	21	20	19	18	17	15	11	6	4	24
7	Cavity Depth	2	2	2	1	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	1
8	Front Cavity Volume	26	26	26	26	26	26	26	26	26	26	26	26	24	24	22	20	17	9	5	31
8	Theory of Adding Volume * 0.5	0	0	0	0	0	0	0	0	0	0	1	2	6	9	14	23	37	60	105	194
9	Compliance	0	0	0	0	0	0	0	0	0	0	2	9	40	66	111	187	268	232	118	593
9	Mass	0	0	0	0	0	0	0	0	0	0	1	3	11	16	21	19	1	25	31	97
9	Resistance	0	0	0	0	0	0	0	0	0	1	4	14	56	86	128	177	196	120	46	237
10	Heat Conduction Theory (see note)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Thermal Diffusivity	154	104	73	52	46	41	37	26	18	13	9	6	5	4	4	3	3	2	2	2
10	Thread Correction	37	25	14	13	16	14	9	7	11	1	5	6	10	2	3	5	3	1	2	7
11	Capillary Radius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Air Viscosity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Leakage																				
12	Humidity Determination	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	5	7
13	Polarising Voltage	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
14	Temperature	4	3	2	2	2	2	1	1	1	1	0	1	1	2	3	4	7	10	17	29
15	Pressure Radial Non-Unif	0	0	0	0	0	0	0	0	0	0	1	6	22	34	54	86	132	203	308	424
16	Mic. Temp. Dependence	24	24	24	24	24	24	24	24	24	24	24	24	24	24	25	28	29	25	38	84
16	Mic. Press. Dependence	32	32	32	32	32	32	32	32	32	32	32	32	33	34	36	41	43	32	89	160
20	Transmitter Ground Shield	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
20	Receiver Ground Shield	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
21	Rounding Error	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
22	Frequency	35	9	3	1	3	2	2	1	0	0	0	0	10	13	15	14	5	19	61	100
	ESTIMATE OF S.D. (σ_B)	220	212	207	206	69	68	67	65	64	64	64	64	76	92	121	170	217	204	219	479
	$\sigma_B = [\Sigma\ (a^2/3)]^{1/2}$																				
									COMPONENTS OF TYPE A UNCERTAINTY EXPRESSED AS STANDARD DEVIATIONS (10												
	SOURCE								Frequency (Hz)												
	Normal distribution with $n \rightarrow \infty$ applies unless stated	2	4	8	16	20	25	32	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
1	Allowed Repeatability	1200	250	150	100	100	100	100	100	100	100	100	100	100	100	100	100	100	125	150	150
8	Front Cavity Volume	38	38	38	38	38	38	38	38	38	38	38	38	36	34	32	28	24	12	6	44
	ESTIMATE OF S.D. (σ_A)	1201	253	155	107	107	107	107	107	107	107	107	107	106	106	105	104	103	126	150	156
	$\sigma_A = [\Sigma\ (a^2)]^{1/2}$																				
									OVERALL UNCERTAINTY (10^{-4} dB)												
	SOURCE								Frequency (Hz)												
		2	4	8	16	20	25	32	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
	Type B at k =2 ($2\sigma_B$)	440	423	414	411	139	136	134	130	129	127	127	128	152	183	243	340	433	407	439	957
	Type A at k =2 ($2\sigma_A$)	2401	506	309	214	214	214	214	214	214	214	214	214	213	211	210	208	206	251	300	313
	Overall Uncertainty at k =2	2441	659	517	464	255	254	252	250	250	249	249	249	261	280	321	399	480	478	532	1007
	$\sigma = 2(\sigma_A^2+\sigma_B^2)^{1/2}$																				
	Quote (dB)	0.25	0.07	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.11

Valid for coupler UA1429

COMPONENTS OF TYPE B UNCERTAINTY EXPRESSED AS SEMI-RANGES (10^{-4} degrees)

	SOURCE Rectangular distribution applies unless stated	2	4	8	16	20	25	31.5	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
		Frequency (Hz)																			
1	Resistor Box Accuracy - Resistance	9	4	2	1	1	1	2	1	1	1	1	1	2	1	2	2	1	1	2	1
1	Resistor Box Accuracy - Capacitor	841	607	529	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	Stray Capacitance					1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
1	Non Linearity	3600	2600	2600	2100	2100	2100	2100	2100	2100	2100	2100	1600	1600	1600	1600	1600	1600	1600	1600	1600
2	Radius of Coupler	2	1	1	1	1	1	0	0	0	0	0	1	1	2	2	2	2	1	7	16
3	Velocity of Sound (dry air)	4	3	3	2	2	1	1	1	0	1	2	5	12	15	20	28	39	53	67	78
4	Ratio of Specific Heats	161	123	92	67	61	55	49	35	26	18	13	9	6	5	4	4	3	2	0	2
5	Ambient Pressure	9	7	5	4	4	3	3	2	1	1	0	1	3	4	5	6	6	4	2	10
6	Density of air	0	0	0	0	0	0	0	0	0	0	1	1	3	3	4	5	5	3	2	8
7	Length of Coupler	11	9	6	5	4	4	3	3	2	2	2	4	7	9	13	19	30	49	74	99
7	Cavity Depth	26	20	16	12	10	10	8	6	4	4	2	2	1	2	4	8	18	38	60	64
8	Front Cavity Volume	32	26	18	14	12	12	10	8	6	4	4	6	8	10	14	18	24	32	46	74
8	Theory of Adding Volume * 0.5	0	0	0	0	1	1	1	1	2	3	7	13	32	38	48	62	82	114	164	262
9	Compliance	2	6	12	24	30	38	46	94	190	380	764	1528	3008	3684	4414	4918	4466	2460	1474	3828
9	Mass	0	0	0	0	0	0	0	0	0	0	2	10	84	162	312	570	824	664	368	2166
9	Resistance	2	2	6	12	14	18	22	44	90	180	358	696	1220	1350	1332	928	12	756	836	2330
10	Heat Conduction Theory (see note)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Thermal Diffusivity	1407	1072	800	588	531	479	430	310	223	159	113	79	53	46	39	31	23	14	1	19
10	Thread Correction	187	139	103	80	72	63	60	42	30	24	18	11	10	8	12	11	11	7	3	10
11	Capillary Radius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Air Viscosity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Leakage																				
12	Humidity Determination	4	3	2	2	1	1	1	1	1	0	0	0	0	0	1	1	2	6	13	20
13	Polarising Voltage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Temperature	29	23	17	13	12	11	10	7	5	4	3	2	2	2	3	6	13	29	54	80
15	Pressure Radial Non-Unif																				
16	Mic. Temp. Dependence	0	0	0	0	0	0	0	0	0	1	2	5	13	16	18	19	18	11	13	77
16	Mic. Press. Dependence	0	0	0	0	0	0	0	0	1	2	7	13	14	6	17	88	248	515	585	192
20	Transmitter Ground Shield	20	10	5	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
20	Receiver Ground Shield	20	10	5	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
21	Rounding Error	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
22	Frequency	0	0	0	0	2	2	2	3	3	29	32	37	416	438	475	542	640	746	724	378
	ESTIMATE OF S.D. (σ_B) $\sigma_B = [\Sigma (a^2/3)]^{1/2}$	2307	1690	1628	1326	1653	1647	1643	1634	1633	1644	1696	1720	2364	2687	3035	3252	3009	2157	1823	3220

COMPONENTS OF TYPE A UNCERTAINTY EXPRESSED AS SEMI-RANGES (10^{-4} degrees)

	SOURCE Normal distribution with $n \to \infty$ applies unless stated	2	4	8	16	20	25	31.5	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
		Frequency (Hz)																			
1	Allowed Repeatability	###	7000	3500	2000	1500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1500	2000
8	Front Cavity Volume	48	39	28	22	20	19	16	12	8	8	6	8	14	16	20	26	34	48	70	112
	ESTIMATE OF S.D. (σ_A) $\sigma_A = [\Sigma (a^2)]^{1/2}$	###	7000	3500	2000	1500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1001	1001	1502	2003

OVERALL UNCERTAINTY (10^{-4} dB)

	SOURCE	2	4	8	16	20	25	31.5	63	125	250	500	1k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
		Frequency (Hz)																			
	Type B at *k* =2 ($2\sigma_B$)	4613	3379	3256	2652	3305	3294	3285	3268	3265	3287	3391	3440	4729	5375	6070	6504	6017	4314	3646	6441
	Type A at *k* =2 ($2\sigma_A$)	###	###	7000	4000	3000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2001	2001	2002	3003	4006
	Overall Uncertainty at *k* =2 $\sigma = 2(\sigma_A^2+\sigma_B^2)^{1/2}$	###	###	7720	4800	4464	3854	3846	3832	3829	3848	3937	3980	5134	5735	6391	6805	6341	4756	4724	7585
	Quote (degrees)	3.3	1.5	0.8	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.7	0.7	0.7	0.5	0.5	0.8

D.3 NMISA

Symbol	LS1P Modulus U calculated with k=2 which approximates 95% — Frequency (Hz)	2.00	2.51	3.16	3.98	5.01	6.31	7.94	10.00	12.59	15.85	19.95	25.12	31.62	39.81	50.12	63.10	79.43	100.00	125.89
		$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)
	Electrical Parameters																			
C_{ref}	Reference capacitor	0.0150	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0090	0.0075	0.0050	0.0038	0.0033	0.0020	0.0018	0.0017	0.0016	0.0015	0.0011	0.0010
Z_e	Voltage ratio	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
$Z_{e,XT}$	Channel cross-talk	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
$T_x R_{x,gs}$ C_s	Transmitter & Receiver driven ground shield & stray capacitance	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	0.0001	0.0001	0.0001
E_0	Polarization voltage	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	0.0008	0.0008	0.0008	0.0008
	Coupler Properties																			
l_c, d_c V_c, S_0	Coupler length, diameter, volume, cross-sectional surface area	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
$L_{m,c}$	Unintentional microphone/coupler leakage	0.0155	0.0123	0.0098	0.0078	0.0062	0.0049	0.0039	0.0031	0.0025	0.002	0.0016	0.0013	0.001	0.0008	0.0007	0.0005	0.0004	0.0004	0.0003
	Radial wave-motion	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	0.000	0.000	0.000
	Microphone Parameters																			
V_f, V_e	Front cavity volume, Equivalent volume (5 mm^3) - curve fitted	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	0.0000
f_0	Resonant frequency (300 Hz) - curve fitted	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	0.0000
d	Loss factor (0,12) - curve fitted	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	0.0000
Δ_{cr}	Heat conduction	0.0235	0.021	0.0187	0.0167	0.0149	0.0133	0.0119	0.0106	0.0094	0.0084	0.0075	0.0067	0.006	0.0053	0.0048	0.0043	0.0038	0.0034	0.003
	Ambient Conditions																			
$p_{s,m}$	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	0.000	0.000	0.000	0.000
t_m	Temperature	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	0.000	0.000	0.000
H_m	Relative humidity	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	0.000	0.000	0.000
	Processing of Results - Type A																			
$E_{c,f}$	Curve fitting ESDM	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	0.006	0.006	0.006	0.006
r_e	Rounding error	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	0.0003
rp	Reproduceability	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
u_c	**Combined Standard Uncertainty (k=1)**	0.034	0.029	0.026	0.024	0.022	0.021	0.020	0.018	0.017	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.011	0.011
U	**Expanded Standard Uncertainty (k=2)**	0.068	0.057	0.052	0.048	0.044	0.042	0.040	0.036	0.033	0.030	0.028	0.027	0.025	0.025	0.024	0.024	0.023	0.023	0.022
U	**Reported Expanded Standard Uncertainty (k=2)**	**0.075**	**0.070**	**0.060**	**0.055**	**0.050**	**0.050**	**0.045**	**0.040**	**0.040**	**0.035**	**0.035**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.025**

Symbol	LS1P Modulus *U* calculated with *k*=2 which approximates 95% — Frequency (Hz)	158.49	199.53	251.19	316.23	398.11	501.19	630.96	794.33	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3	10000.0
		$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)
	Electrical Parameters																			
C_{ref}	Reference capacitor	0.0010	0.0010	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0005	0.0004	0.0003	0.0002	0.0003	0.0007	0.0015	0.0019	0.0020	0.0027	0.0033
Z_e	Voltage ratio	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
$Z_{e,XT}$	Channel cross-talk	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
$T_x R_{x,gs}$ C_s	Transmitter & Receiver driven ground shield & stray capacitance	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0003	0.0003	0.0002	0.0002
E_0	Polarization voltage	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	0.0008	0.0008	0.0008	0.0008
	Coupler Properties																			
l_c, d_c V_c, S_0	Coupler length, diameter, volume, cross-sectional surface area	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.006	0.004
$L_{m,c}$	Unintentional microphone/coupler leakage	0.0002	0.0001	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	0.000
	Radial wave-motion	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0001	0.0002	0.0002	0.0004	0.0006	0.0008	0.0013	0.0022	0.0034	0.0049	0.0063	0.0086
	Microphone Parameters																			
V_f, V_e	Front cavity volume, Equivalent volume (5 mm^3) - curve fitted	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0004	0.0007	0.0011	0.0017	0.0026	0.0037	0.0048	0.0059	0.0117
f_0	Resonant frequency (300 Hz) - curve fitted	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004	0.0006	0.0010	0.0016	0.0029	0.0050	0.0067	0.0017	0.0081
d	Loss factor (0,12) - curve fitted	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004	0.0006	0.0010	0.0016	0.0025	0.0039	0.0061	0.0095	0.0132	0.0132	0.0059	0.0170
Δ_{cr}	Heat conduction	0.0027	0.0024	0.0022	0.0019	0.0017	0.0016	0.0014	0.0012	0.0011	0.001	0.0009	0.0008	0.0008	0.0015	0.0024	0.0037	0.0064	0.0038	0.0001
	Ambient Conditions																			
$p_{s,m}$	Static pressure	0.000	0.000	0.000	0.000	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
t_m	Temperature	0.000	0.000	0.000	0.000	0.00003	0.00003	0.00003	0.00003	0.00004	0.00004	0.00004	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00005	0.00013
H_m	Relative humidity	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0001	0.0002	0.0020	0.0030	0.0040	0.0060	0.0090	0.0130	0.0120	0.0029	0.0036	0.0031	0.0004
	Processing of Results - Type A																			
$E_{c,f}$	Curve fitting ESDM	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	0.009	0.010	0.011	0.020
r_e	Rounding error	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	0.0003
rp	Reproduceability	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	0.0025	0.004	0.005	0.009	0.01	0.02
u_c	**Combined Standard Uncertainty (*k*=1)**	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.012	0.012	0.013	0.015	0.018	0.020	0.021	0.024	0.020	0.037
U	**Expanded Standard Uncertainty (*k*=2)**	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.023	0.023	0.023	0.026	0.029	0.037	0.040	0.041	0.048	0.041	0.075
U	**Reported Expanded Standard Uncertainty (k=2)**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.030**	**0.035**	**0.040**	**0.045**	**0.045**	**0.050**	**0.060**	**0.075**	**0.090**

Symbol	Frequency (Hz)	2.00	2.51	3.16	3.98	5.01	6.31	7.94	10.00	12.59	15.85	19.95	25.12	31.62	39.81	50.12	63.10	79.43	100.00	125.89
Symbol	**LS1P Phase *U*** **calculated with *k*=2 which approximates 95%**	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (dB)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)
	Electrical Parameters																			
Θa	Phase accuracy	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	0.0029	0.0029	0.0029	0.0029
$\Theta Cref$	Reference capacitor	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	0.0000
Θf	Frequency accuracy	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	0.0000
Θ_{Res}	Phase resolution of Analyzer	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	0.0003
$\Theta T_x R_{x,gs}$ $_\Theta C_s$	Transmitter & Receiver driven ground shield & stray capacitance	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
	Coupler Properties																			
$\Theta l_c, \Theta d_c$ $\Theta V_c, \Theta S_0$	Coupler length, diameter, volume, cross-sectional surface area	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	0.001	0.001	0.001
$\Theta L_{m,c}$	Unintentional microphone/coupler leakage	0.0751	0.059	0.0472	0.0372	0.0294	0.0234	0.0186	0.0147	0.0137	0.0093	0.0081	0.0057	0.0043	0.003	0.0019	0.0004	0.0002	-0.0005	-0.0006
	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	0.0000
	Microphone Parameters																			
$\Theta V_f, \Theta V_e$	Front cavity volume, Equivalent volume (5 mm^3) - curve fitted	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0003	0.0004	0.0005	0.0006
Θf_0	Resonant frequency (300 Hz) - curve fitted	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	0.0001	0.0002	0.0004	0.0006
Θd	Loss factor (0,12) - curve fitted	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0007	0.0008	0.0011	0.0014	0.0017	0.0022	0.0027	0.0034
$\Theta \Delta_{cr}$	Heat conduction	0.0301	0.0267	0.0236	0.0209	0.0185	0.0163	0.0145	0.0128	0.0113	0.0100	0.0091	0.0082	0.0073	0.0066	0.0059	0.0053	0.0048	0.0043	0.0038
	Ambient Conditions																			
$\Theta p_{s,\Delta+m}$	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	0.000	0.000	0.000	0.000
$\Theta t_{\Delta+m}$	Temperature	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	0.000	0.000	0.000
$\Theta H_{\Delta+m}$	Relative humidity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Processing of Results - Type A																			
$\Theta E_{c,f}$	Curve fitting	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	0.0014	0.0014	0.0014	0.0014
Θr_e	Rounding error	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	0.0029	0.0029	0.0029	0.0029
Θrp	Reproduceability	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	0.02	0.01	0.01	0.01	0.01	0.01
	Uncertainty quoted in degrees (°)																			
Θu_c	**Combined Standard Uncertainty (*k*=1)**	0.085	0.067	0.056	0.046	0.039	0.033	0.029	0.026	0.025	0.022	0.021	0.020	0.019	0.019	0.014	0.013	0.013	0.013	0.013
ΘU	**Expanded Standard Uncertainty (*k*=2)**	0.17	0.13	0.11	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
ΘU	**Reported Expanded Standard Uncertainty (k=2)**	**0.20**	**0.20**	**0.15**	**0.15**	**0.10**	**0.10**	**0.08**	**0.08**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**

Symbol	Frequency (Hz) **LS1P Phase *U*** **calculated with *k*=2 which approximates 95%**	158.49	199.53	251.19	316.23	398.11	501.19	630.96	794.33	1000.0	1258.9	1584.9	1995.3	2511.9	3162.3	3981.1	5011.9	6309.6	7943.3	10000.0
		$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)	$u(x_i)$ (°)
	Electrical Parameters																			
Θ_a	Phase accuracy	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	0.0029	0.0029	0.0029	0.0029
Θ_{Cref}	Reference capacitor	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	0.0000
Θf	Frequency accuracy	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	0.0000
Θ_{Res}	Phase resolution of Analyzer	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	0.0003
$\Theta T_x R_{x,gs}$ ΘC_s	Transmitter & Receiver driven ground shield & stray capacitance	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	0.004	0.004	0.007
	Coupler Properties																			
Θl_c, Θd_c ΘV_c, ΘS_0	Coupler length, diameter, volume, cross-sectional surface area	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.004	0.005	0.007	0.008	0.008	0.007
$\Theta L_{m,c}$	Unintentional microphone/coupler leakage	-0.0007	-0.0005	0.0003	-0.0004	-0.0006	0.0007	-0.0003	0.002	0.001	0.001	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	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	0.0000
	Microphone Parameters																			
ΘV_f, Θv_e	Front cavity volume, Equivalent volume (5 mm^3) - curve fitted	0.0008	0.0010	0.0013	0.0016	0.0020	0.0026	0.0033	0.0042	0.0053	0.0067	0.0084	0.0105	0.0130	0.0160	0.0193	0.0214	0.0166	0.0037	0.0347
Θf_0	Resonant frequency (300 Hz) - curve fitted	0.0008	0.0011	0.0014	0.0017	0.0021	0.0026	0.0030	0.0036	0.0042	0.0050	0.0063	0.0084	0.0118	0.0166	0.0217	0.0235	0.0177	0.0157	0.0923
Θd	Loss factor (0,12) - curve fitted	0.0043	0.0055	0.0069	0.0087	0.0110	0.0138	0.0173	0.0217	0.0272	0.0323	0.0400	0.0499	0.0614	0.0706	0.0681	0.0416	0.0044	0.0604	0.2131
$\Theta \Delta_{cr}$	Heat conduction	0.0034	0.0030	0.0027	0.0024	0.0022	0.0019	0.0017	0.0015	0.0013	0.0012	0.0010	0.0009	0.0008	0.0007	0.0005	0.0003	0.0001	0.0001	0.0006
	Ambient Conditions																			
$\Theta p_{s,\Delta+m}$	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	0.0001	0.0001	0.0001	0.0001
$\Theta t_{\Delta+m}$	Temperature	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	0.000	0.000	0.000
$\Theta H_{\Delta+m}$	Relative humidity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.07
	Processing of Results - Type A																			
$\Theta E_{c,f}$	Curve fitting	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	0.0014	0.0014	0.0014	0.0014
Θr_e	Rounding error	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	0.0029	0.0029	0.0029	0.0029
Θrp	Reproduceability	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.06	0.07	0.15
	Uncertainty quoted in degrees (°)																			
Θu_c	**Combined Standard Uncertainty (*k*=1)**	0.014	0.014	0.014	0.015	0.017	0.019	0.021	0.025	0.030	0.035	0.043	0.053	0.067	0.077	0.080	0.073	0.069	0.103	0.288
ΘU	**Expanded Standard Uncertainty (*k*=2)**	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.09	0.11	0.13	0.15	0.16	0.15	0.14	0.21	0.58
ΘU	**Reported Expanded Standard Uncertainty (k=2)**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.10**	**0.10**	**0.15**	**0.15**	**0.15**	**0.20**	**0.20**	**0.20**	**0.30**	**0.40**	**0.55**	**0.70**

D.4 VTT MIKES

Sensitivity magnitude uncertainty [dB]																											
f[Hz]	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100.0**	**125.0**	**160.0**	**200.0**	**250.0**	**315.0**	**400.0**	**500.0**	**630.0**	**800.0**	**1000.0**	**1250.0**	**1600.0**	**2000.0**	**2500.0**	**3150.0**	**4000.0**	**5000.0**	**6300.0**	**8000.0**	**10000.0**
Temparature	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Relative Humidity	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	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0003	0.0003
Barometric Pressure	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0014	0.0014	0.0014	0.0014	0.0015	0.0016	0.0017	0.0020	0.0023	0.0026	0.0023	0.0011
Total Volume	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0064	0.0064	0.0064	0.0065	0.0066	0.0067	0.0068	0.0070	0.0072	0.0071	0.0060	0.0040
Distance between Diaphragms	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	0.0001	0.0001	0.0002	0.0003	0.0004	0.0007	0.0012	0.0019	0.0032	0.0051	0.0073	0.0089
Total Area	0.0008	0.0007	0.0006	0.0005	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
Heat Conduction Correction	0.0107	0.0098	0.0088	0.0078	0.0070	0.0062	0.0055	0.0049	0.0044	0.0039	0.0035	0.0031	0.0027	0.0024	0.0022	0.0019	0.0030	0.0026	0.0023	0.0020	0.0017	0.0015	0.0012	0.0009	0.0005	0.0001	0.0002	0.0004
Capillary Correction	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Wavemotion Correction	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	0.0001	0.0005	0.0008	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 Wavemotion Correction	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	0.0001	0.0001	0.0002	0.0003	0.0004	0.0007	0.0011	0.0017	0.0022	0.0022	0.0021
Temperature Correction	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pressure Correction	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0003
Voltage Ratio	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0058	0.0059	0.0059	0.0059	0.0060	0.0061	0.0062	0.0064	0.0066	0.0065	0.0055	0.0036
Reference Capacitance	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0003
Polarization Voltage	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0003
Ratio of Spesific Heats	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	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0017	0.0016	0.0013	0.0007	0.0001
Air Density	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0003	0.0003
Air Temperature Conductivity	0.0005	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
Air Viscocity	0.0000	0.0000	0.0000	0.0001	0.0001	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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Equivalent Volume	0.0094	0.0094	0.0094	0.0095	0.0095	0.0095	0.0095	0.0095	0.0096	0.0096	0.0096	0.0097	0.0098	0.0099	0.0100	0.0102	0.0104	0.0107	0.0110	0.0115	0.0121	0.0130	0.0141	0.0158	0.0183	0.0220	0.0279	0.0380
Repeatability (A)	0.0195	0.0180	0.0160	0.0144	0.0130	0.0121	0.0115	0.0112	0.0111	0.0111	0.0111	0.0111	0.0111	0.0112	0.0112	0.0113	0.0113	0.0114	0.0116	0.0117	0.0120	0.0123	0.0128	0.0134	0.0145	0.0161	0.0188	0.0238
Residual (A)	0.0090	0.0083	0.0084	0.0061	0.0093	0.0071	0.0045	0.0068	0.0044	0.0044	0.0067	0.0035	0.0037	0.0032	0.0035	0.0027	0.0006	0.0007	0.0007	0.0005	0.0007	0.0004	0.0011	0.0012	0.0021	0.0035	0.0033	0.0093
Type B overall uncertainty	0.0159	0.0154	0.0147	0.0141	0.0137	0.0133	0.0130	0.0128	0.0126	0.0125	0.0124	0.0123	0.0123	0.0123	0.0124	0.0125	0.0141	0.0142	0.0144	0.0148	0.0153	0.0161	0.0172	0.0188	0.0212	0.0248	0.0302	0.0395
Type A overall uncertainty	0.0215	0.0198	0.0181	0.0156	0.0160	0.0140	0.0123	0.0131	0.0119	0.0119	0.0130	0.0116	0.0117	0.0116	0.0118	0.0116	0.0114	0.0115	0.0116	0.0118	0.0120	0.0123	0.0128	0.0135	0.0146	0.0164	0.0191	0.0256
Combined Standard Uncertainty (k=1)	0.0268	0.0251	0.0233	0.0211	0.0211	0.0193	0.0179	0.0183	0.0174	0.0172	0.0179	0.0169	0.0170	0.0169	0.0171	0.0170	0.0181	0.0183	0.0185	0.0189	0.0195	0.0203	0.0214	0.0231	0.0258	0.0298	0.0357	0.0470
Expanded Uncertainty (k=2)	0.0535	0.0501	0.0466	0.0421	0.0421	0.0387	0.0359	0.0366	0.0347	0.0345	0.0358	0.0339	0.0340	0.0338	0.0341	0.0341	0.0362	0.0365	0.0370	0.0378	0.0389	0.0405	0.0429	0.0463	0.0515	0.0595	0.0714	0.0940
Stated Uncertainty (k=2)	**0.054**	**0.050**	**0.047**	**0.042**	**0.042**	**0.039**	**0.036**	**0.037**	**0.035**	**0.034**	**0.036**	**0.034**	**0.034**	**0.034**	**0.034**	**0.034**	**0.036**	**0.037**	**0.037**	**0.038**	**0.039**	**0.041**	**0.043**	**0.046**	**0.052**	**0.060**	**0.071**	**0.094**