Final Report on Key Comparison

APMP.AUV.V-K3

This comparison was initially registered as APMP.AUV.V-S1, but was redefined as APMP.AUV.V-K3 in November 2013

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2012-12-12

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1 Introduction

This report presents the results of the first Asia Pacific Metrology Programme (APMP) comparison in the area of low-frequency 'vibration', which in this case means sinusoidal acceleration.

The participants have reached consensus and considered the weighted mean as the most appropriate method for this particular comparison to compute the key comparison reference values (KCRVs) and the degrees of equivalence. Detailed analysis and application of the method for use in comparisons in the field of vibration, is documented in the CCAUV.V-K1 report [1]. The calculation of the KCRVs is also in accordance with the Guidelines for CIPM key comparisons [2].

The Technical Protocol of December 2010 [3] specifies in detail the aim and the task of the comparison, the conditions of measurement, the transfer standards used, measurement instructions, time schedule and other items. A brief survey is given in the following sections.

2 Participants

Seven metrology institutes from APMP economies have participated in the comparison APMP.AUV.V-K3 (see table 1).

Table 1: List of participating institutes

Participant	Economy	Calibration period
NIM	P. R. China	August, 2011
NIMT	Thailand	September, 2011
CMS/ITRI	Chinese Taipei	September, 2011
NMIA	Australia	October, 2011
NMISA	South Africa	November, 2011
NMIJ	Japan	December, 2011
KRISS	Korea	April, 2012

3 Task and Purpose of the Comparison

Recent developments in technology and improvements at the NMIs have extended the low-frequency vibration limit of calibration capabilities down to 0.5 Hz and even as low as 0.1 Hz. Therefore, during the meeting of APMP TCAUV in 2008, the decision was taken to make preparations for a further comparison targeted at a low-frequency range.

In the field of vibration, this regional key comparison was organized in order to compare measurements of sinusoidal linear accelerations in the frequency range from 0.5 Hz to 20 Hz. Moreover, the magnitude of the complex sensitivity calibration and measurement capabilities (CMCs) of the participating laboratories for accelerometer calibration were to be examined and compared. The phase shift was optional. It was the task of the comparison to measure the magnitude of the complex sensitivity of two accelerometer standard sets (one set included a quartz-flexure servo accelerometer of single-ended type and a signal conditioner) at different frequencies with acceleration amplitudes as specified in section 3 of [3]. The results of this APMP comparison will, after approval by CCAUV, serve as empirical support for the registration of low-frequency vibration 'calibration and measurement capabilities' (CMCs) in the framework of the CIPM MRA.

The voltage sensitivity is calculated as the ratio of the amplitude of the accelerometer standard set output voltage to the amplitude of the acceleration at its reference surface. The magnitude of the complex voltage sensitivity was given in millivolts per meter per second squared (mV/(m/s^2)) for the different measurement conditions specified in section 4 of [3].

For the calibration of the accelerometer standard sets, laser interferometry in compliance with method 1 or method 3 of the international standard ISO 16063-11:1999 [4] had to be applied, in order to cover the entire frequency range.

The reported sensitivities and associated uncertainties of measurement were used for the calculation of the key comparison reference value (KCRV).

4 Conditions and Instructions of Measurement

The participating laboratories observed to a large extent the conditions stated in the Technical Protocol, i.e.

- frequencies in Hz:
  0.5, 0.63, 0.8, 1, 1.25, 1.6 (reference frequency), 2, 2.5, 3.15, 4, 5, 6.3, 8, 10, 12.5, 16, 20.
- acceleration amplitudes:
  A range of 0.1 m/s^2 to 10 m/s^2 was admissible.
- ambient temperature and accelerometer temperature during the calibration:
  (23 ± 2) ºC (actual values to be stated within tolerances of ± 0.3 ºC).

- relative humidity: max. 75 % RH

The comparison was performed in compliance with the “Guidelines for CIPM key comparisons” [2].

5 Transfer Standards as Artefacts

For the purpose of the comparison the pilot laboratory selected two accelerometers of which monitoring data for 6 months were available and of which data were not included in any published international cooperation work. Their pictures are in Figure 1.

- One transfer standard accelerometer (single-ended), type SA704, S/N 1021 (manufacturer: NIM) referred to as SE-1021.
- One transfer standard accelerometer (single-ended), type SA704, S/N 1022 (manufacturer: NIM) referred to as SE-1022 .
- One signal conditioner, type MSA-I, S/N 02011001 (manufacturer: NIM).

The investigation of the long-term stability was continued throughout the circulation period. The results of the NIM stability measurements and other individual data of the transfer standards are given in Section 7.

Figure 1: Two transfer standard accelerometers

6 Circulation of the Artefacts

The transducer sets were circulated in a star type fashion with a measurement period of two weeks provided for each participating laboratory and one week for the pilot laboratory. At the beginning and the end of the circulation as well as between certain subsequent measurements of participating laboratories, the transducer sets were measured by the pilot laboratory in order to determine reference values and to monitor the stability of the transducer sets (c.f. section 7). Due to the unexpected earthquake and tsunami which occurred in March 2011, the circulation had to be modified to incorporate two loops. The first loop was from NIM to NIMT, to CMS and back to NIM. The second loop was from

NIM to NMIA, to NMISA, to NMIJ, to KRISS and back to NIM.

The input range of SA-704 is 600 m/s^2 and the highest environment shock 1000 m/s^2. Therefore, any violent drop could change its sensitivity or even damage it. The transducer sets had to be hand-carried with great caution, shown in Figure 2.

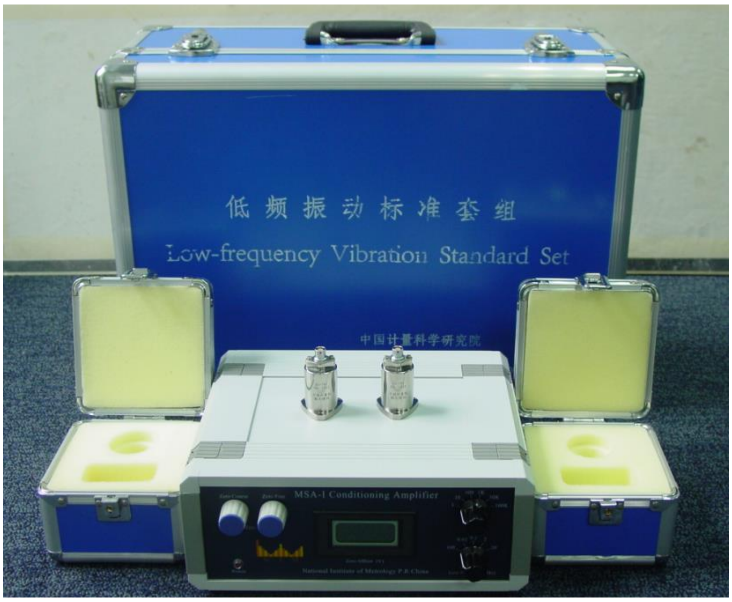


Figure 2: Package of transfer standard set including two accelerometers and one signal conditioner

7 Results of the Measurements

7.1 Monitoring of stability

Starting with calibration data in February 2011, the artefacts were monitored during the preparatory period and the intervals of the comparison when they were back at the pilot laboratory. As a representative of the overall change, the measurements at reference frequency (1.6 Hz) are given in the following tables, with both the horizontal and vertical installation of artefacts.

Table 2: Horizontal voltage sensitivities of the SE-1021 at 1.6 Hz

during the monitoring measurements

Month rel. to 2/2011	S_{va} in mV/(m/s²)	rel. exp. Uncertainty in %
0	124.09	0.2
2	124.11	0.2
4	124.12	0.2
6	124.11	0.2
8	124.09	0.2
16	124.07	0.2

Table 3: Vertical voltage sensitivities of the SE-1021 at 1.6 Hz

during the monitoring measurements

Month rel. to 2/2011	S_{va} in mV/(m/s²)	rel. exp. Uncertainty in %
0	124.07	0.2
2	124.09	0.2
4	124.10	0.2
6	124.09	0.2
8	124.08	0.2
16	124.09	0.2

Table 4: Horizontal voltage sensitivities of the SE-1022 at 1.6 Hz

during the monitoring measurements

Month rel. to 2/2011	S_{va} in mV/(m/s²)	rel. exp. Uncertainty in %
0	123.95	0.2
2	124.00	0.2
4	124.00	0.2
6	123.99	0.2
8	123.97	0.2
16	123.94	0.2

Table 5: Vertical voltage sensitivities of the SE-1022 at 1.6 Hz

during the monitoring measurements

Month rel. to 2/2011	S_{va} in mV/(m/s²)	rel. exp. Uncertainty in %
0	123.94	0.2
2	123.98	0.2
4	123.98	0.2
6	123.97	0.2
8	123.96	0.2
16	123.95	0.2

These monitoring measurements can in the simplest way be summarized by the following statistical properties. It indicates that the stability of the artefacts was good considering the uncertainty claimed by the pilot laboratory in Appendix B.

Table 6: Mean and standard deviation of the voltage sensitivity of the artefacts

calculated from the monitoring measurements

Artefact	long term mean in mV/(m/s²)	rel. std. deviation in %
SE-1021 (Horizontal)	124.098	0.01
SE-1021 (Vertical)	124.098	0.01
SE-1022 (Horizontal)	123.975	0.02
SE-1022 (Vertical)	123.963	0.01

7.2 Results of the Participants

It should be noted that the measurement results from the pilot laboratory were sent to the CCAUV Secretary prior to the circulation of the artefacts. The results include voltage sensitivities and phase shift of the two accelerometers in both horizontal and vertical installation directions.

7.2.1 Results of horizontal voltage sensitivities of the SE-1021

Table 7: Reported calibration results in mV/(m/s²) of the participants for horizontal voltage sensitivities of the SE-1021 with expanded relative uncertainty (*k* = 2) in %

	NIM		CMS		NMIA	
Frequency (Hz)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)
0.50	124.33	0.2	124.7	2.7	124.08	0.2
0.63	124.26	0.2	125.0	2.7	124.07	0.2
0.80	124.22	0.2	124.9	2.4	124.05	0.2
1.00	124.14	0.2	125.3	2.3	124.04	0.2
1.25	124.12	0.2	125.0	2.3	124.03	0.2
1.60	124.11	0.2	125.3	2.3	124.02	0.2
2.00	124.13	0.2	124.7	2.3	124.02	0.2
2.50	124.12	0.2	124.4	2.2	124.01	0.2
3.15	124.12	0.2	124.4	0.5	124.01	0.2
4.00	124.13	0.2	124.8	0.5	124.01	0.2
5.00	124.14	0.2	124.4	0.5	124.01	0.2
6.30	124.14	0.2	124.6	0.5	124.02	0.2
8.00	124.16	0.2	124.6	0.5	124.03	0.2
10.00	124.23	0.2	124.3	0.5	124.06	0.2
12.50	124.25	0.2	124.8	0.4	124.11	0.2
16.00	124.35	0.2	125.0	0.5	124.20	0.2
20.00	124.50	0.2	124.9	0.5	124.33	0.2

Table 8: Reported calibration results in mV/(m/s²) of the participants for horizontal voltage sensitivities of the SE-1021 with expanded relative uncertainty (k = 2) in %

	NMISA		NMIJ		KRISS	
Frequency (Hz)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)
0.50	123.9	0.3	124.81	2.0	124.27	0.5
0.63	123.9	0.3	123.93	0.8	124.23	0.5
0.80	123.9	0.3	123.85	0.8	124.13	0.3
1.00	124.0	0.3	123.91	0.9	124.13	0.5
1.25	124.0	0.3	123.76	0.7	124.06	0.3
1.60	124.0	0.3	123.79	0.5	124.07	0.4
2.00	124.0	0.3	123.88	0.7	124.16	0.3
2.50	124.0	0.3	-	-	124.12	0.3
3.15	123.9	0.3	-	-	124.03	0.3
4.00	124.0	0.3	-	-	124.01	0.3
5.00	124.0	0.3	-	-	124.05	0.3
6.30	124.0	0.3	-	-	123.97	0.3
8.00	124.0	0.3	-	-	123.98	0.4
10.00	124.1	0.3	-	-	124.01	0.4
12.50	124.1	0.3	-	-	124.05	0.4
16.00	124.1	0.3	-	-	124.20	0.3
20.00	124.3	0.3	-	-	124.27	0.3

7.2.2 Results of vertical voltage sensitivities of the SE-1021

Table 9: Reported calibration results in mV/(m/s²) of the participants for vertical voltage sensitivities of the SE-1021 with expanded relative uncertainty (k = 2) in %

	NIM		NIMT		NMIJ	
Frequency (Hz)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)
0.50	124.17	0.2	124.06	0.6	-	-
0.63	124.16	0.2	124.06	0.6	-	-
0.80	124.15	0.2	124.06	0.6	-	-
1.00	124.10	0.2	124.06	0.5	-	-
1.25	124.09	0.2	124.06	0.5	-	-
1.60	124.09	0.2	124.06	0.5	-	-
2.00	124.10	0.2	124.06	0.5	-	-
2.50	124.11	0.2	124.06	0.5	123.86	0.3
3.15	124.11	0.2	124.06	0.5	123.91	0.3
4.00	124.11	0.2	124.07	0.5	123.94	0.3
5.00	124.12	0.2	124.10	0.4	123.95	0.3
6.30	124.11	0.2	124.10	0.4	123.98	0.3
8.00	124.14	0.2	124.12	0.4	124.01	0.3
10.00	124.16	0.2	124.15	0.4	124.05	0.3
12.50	124.20	0.2	124.20	0.4	124.11	0.3
16.00	124.30	0.2	124.28	0.4	124.20	0.3
20.00	124.42	0.2	124.41	0.4	124.34	0.3

7.2.3 Results of horizontal voltage sensitivities of the SE-1022

Table 10: Reported calibration results in mV/(m/s²) of the participants for horizontal voltage sensitivities of the SE-1022 with expanded relative uncertainty (k = 2) in %

	NIM		CMS		NMIA	
Frequency (Hz)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)
0.50	124.20	0.2	124.9	2.6	123.94	0.2
0.63	124.13	0.2	124.9	2.7	123.93	0.2
0.80	124.09	0.2	124.8	2.5	123.91	0.2
1.00	124.01	0.2	125.1	2.3	123.90	0.2
1.25	123.97	0.2	124.8	2.3	123.89	0.2
1.60	123.99	0.2	125.0	2.3	123.88	0.2
2.00	123.99	0.2	124.7	2.3	123.88	0.2
2.50	123.99	0.2	124.3	2.2	123.87	0.2
3.15	124.00	0.2	124.9	0.6	123.87	0.2
4.00	124.00	0.2	124.7	0.6	123.87	0.2
5.00	124.01	0.2	124.1	0.5	123.87	0.2
6.30	124.01	0.2	124.1	0.5	123.87	0.2
8.00	124.04	0.2	124.2	0.5	123.89	0.2
10.00	124.11	0.2	124.6	0.5	123.92	0.2
12.50	124.11	0.2	124.4	0.5	123.96	0.2
16.00	124.20	0.2	124.8	0.5	124.05	0.2
20.00	124.34	0.2	124.6	0.5	124.16	0.2

Table 11: Reported calibration results in mV/(m/s²) of the participants for horizontal voltage sensitivities of the SE-1022 with expanded relative uncertainty (k = 2) in %

	NMISA		NMIJ		KRISS	
Frequency (Hz)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)	S_{va} (mV/(m/s²))	U_c (%)
0.50	123.8	0.3	124.02	2.0	124.12	0.5
0.63	123.8	0.3	123.63	0.7	124.01	0.5
0.80	123.8	0.3	123.81	0.8	123.97	0.3
1.00	123.8	0.3	123.73	1.0	123.94	0.4
1.25	123.8	0.3	123.67	0.7	123.90	0.4
1.60	123.8	0.3	123.68	0.4	123.92	0.4
2.00	123.8	0.3	123.56	0.7	124.01	0.3
2.50	123.8	0.3	-	-	123.99	0.3
3.15	123.9	0.3	-	-	123.90	0.3
4.00	123.8	0.3	-	-	123.86	0.3
5.00	123.9	0.3	-	-	123.83	0.3
6.30	123.9	0.3	-	-	123.80	0.3
8.00	123.9	0.3	-	-	123.82	0.4
10.00	123.9	0.3	-	-	123.86	0.4
12.50	123.9	0.3	-	-	123.89	0.4
16.00	124.0	0.3	-	-	124.03	0.4
20.00	124.1	0.3	-	-	124.09	0.4

7.2.4 Results of vertical voltage sensitivities of the SE-1022

Table 12: Reported calibration results in mV/(m/s²) of the participants for vertical voltage sensitivities of the SE-1022 with expanded relative uncertainty (k = 2) in %

	NIM		NIMT		NMIJ	
Frequency (Hz)	S_{va} (mV/ (m/s²))	U_c (%)	S_{va} (mV/ (m/s²))	U_c (%)	S_{va} (mV/ (m/s²))	U_c (%)
0.50	124.02	0.2	123.92	0.6	-	-
0.63	124.04	0.2	123.92	0.6	-	-
0.80	124.04	0.2	123.92	0.6	-	-
1.00	123.98	0.2	123.92	0.5	-	-
1.25	123.97	0.2	123.93	0.5	-	-
1.60	123.97	0.2	123.93	0.5	-	-
2.00	123.98	0.2	123.93	0.5	-	-
2.50	123.98	0.2	123.93	0.5	123.71	0.3
3.15	123.98	0.2	123.93	0.5	123.77	0.3
4.00	123.99	0.2	123.94	0.5	123.80	0.3
5.00	123.99	0.2	123.96	0.4	123.82	0.3
6.30	123.99	0.2	123.97	0.4	123.85	0.3
8.00	124.00	0.2	123.98	0.4	123.88	0.3
10.00	124.02	0.2	124.01	0.4	123.91	0.3
12.50	124.07	0.2	124.05	0.4	123.97	0.3
16.00	124.13	0.2	124.13	0.4	124.05	0.3
20.00	124.24	0.2	124.25	0.4	124.17	0.3

7.3 Key Comparison Reference Value

The weighted mean was agreed upon by all laboratories to calculate the KCRVs for the APMP.AUV.V-K3 data. KCRVs were calculated separately at each frequency point measured (17 points in total) for both accelerometers in the horizontal direction and the vertical direction.

Calculation of KCRVs using the weighted mean method

Tables 7 to 12 contain the data for the accelerometers reported by the participating laboratories. For each laboratory i these data are (1) $x_{i,f}$: best estimate of sensitivity at frequency *f*, and (2) $u\left(x_{i,f}\right)$: associated standard uncertainty of sensitivity reported at frequency *f*.

For the transfer standards and at each frequency *f*, a key comparison reference value x_{WM} has been determined as the weighted mean of the results of *n* laboratories (for this comparison, *n* = 7) according to

$$x_{\mathrm{WM}} = \frac{\sum_{i=1}^{n} \frac{x_{i,f}}{u^2(x_{i,f})}}{\sum_{i=1}^{n} \frac{1}{u^2(x_{i,f})}} \tag{1}$$

$$u^2(x_{\mathrm{WM}}) = \frac{1}{\sum_{i=1}^{n} \frac{1}{u^2(x_{i,f})}} \tag{2}$$

These calculated KCRVs are reported in Table 13.

The degree of equivalence, $D_{\mathrm{lab-WM}}$, and $U_{\mathrm{lab-WM}}$, was determined for the magnitude measurements for the accelerometer using

$$D_{\mathrm{lab-WM}} = X_{\mathrm{lab}} - X_{\mathrm{WM}}, \quad U_{\mathrm{lab-WM}} = k \cdot \sqrt{u_{\mathrm{lab}}{}^2 - u_{\mathrm{WM}}{}^2} \tag{3}$$

where X_{lab} represents the measurement results obtained by the laboratory at each frequency point for the magnitude and X_{WM} represents the reference value (KCRV) calculated as the weighted mean using Eq. (1). $U_{\mathrm{lab-WM}}$ is the uncertainty of measurement associated with the calculated $D_{\mathrm{lab-WM}}$ for *k* = 2. The calculated degrees of equivalence are completely reported in Appendix C and partly shown in Figures 3 to 10 for SE-1021 and SE-1022 in both horizontal and vertical installation at 0.5 Hz, 1.6 Hz, 10 Hz and 16 Hz.

Application of the weighted mean is justified when the data including the stated uncertainties are consistent with one another. To check this, the following criterion of chi-squared test has been applied:

$$\min_{\zeta} \sum_{i=1}^{n} (x_{i,f} - \zeta)^2 / u^2(x_{i,f}) \le (n-1) + k\sqrt{2(n-1)} \tag{4}$$

where *n* denotes the number of laboratories concerned, cf., e.g., [1] and *k* = 3. All the measurement results passed the consistency test.

Table 13: Reference values and associated expanded uncertainty (k = 2) in mV/(m/s²) for SE-1021 and SE-1022 in horizontal and vertical directions

Frequency (Hz)	1021H		1021V		1022H		1022V	
	X_{WM}	U_{WM}	X_{WM}	U_{WM}	X_{WM}	U_{WM}	X_{WM}	U_{WM}
	in mV/(m/s^2)		in mV/(m/s^2)		in mV/(m/s^2)		in mV/(m/s^2)	
0.50	**124.17**	0.15	**124.16**	0.24	**124.03**	0.15	**124.01**	0.24
0.63	**124.12**	0.15	**124.15**	0.24	**123.97**	0.15	**124.03**	0.24
0.80	**124.10**	0.14	**124.14**	0.24	**123.96**	0.14	**124.03**	0.24
1.00	**124.07**	0.15	**124.09**	0.23	**123.94**	0.15	**123.97**	0.23
1.25	**124.05**	0.14	**124.09**	0.23	**123.91**	0.15	**123.96**	0.23
1.60	**124.04**	0.15	**124.09**	0.23	**123.90**	0.14	**123.96**	0.23
2.00	**124.07**	0.14	**124.09**	0.23	**123.92**	0.14	**123.97**	0.23
2.50	**124.06**	0.15	**124.04**	0.20	**123.92**	0.15	**123.90**	0.20
3.15	**124.06**	0.14	**124.05**	0.20	**123.95**	0.14	**123.92**	0.20
4.00	**124.08**	0.14	**124.06**	0.20	**123.94**	0.14	**123.93**	0.20
5.00	**124.07**	0.14	**124.07**	0.19	**123.92**	0.14	**123.94**	0.19
6.30	**124.08**	0.14	**124.07**	0.19	**123.92**	0.14	**123.95**	0.19
8.00	**124.10**	0.15	**124.10**	0.19	**123.96**	0.15	**123.96**	0.19
10.00	**124.13**	0.15	**124.13**	0.19	**124.02**	0.15	**123.99**	0.19
12.50	**124.21**	0.14	**124.17**	0.19	**124.03**	0.15	**124.04**	0.19
16.00	**124.28**	0.14	**124.27**	0.19	**124.13**	0.15	**124.11**	0.19
20.00	**124.41**	0.14	**124.40**	0.19	**124.23**	0.15	**124.22**	0.19

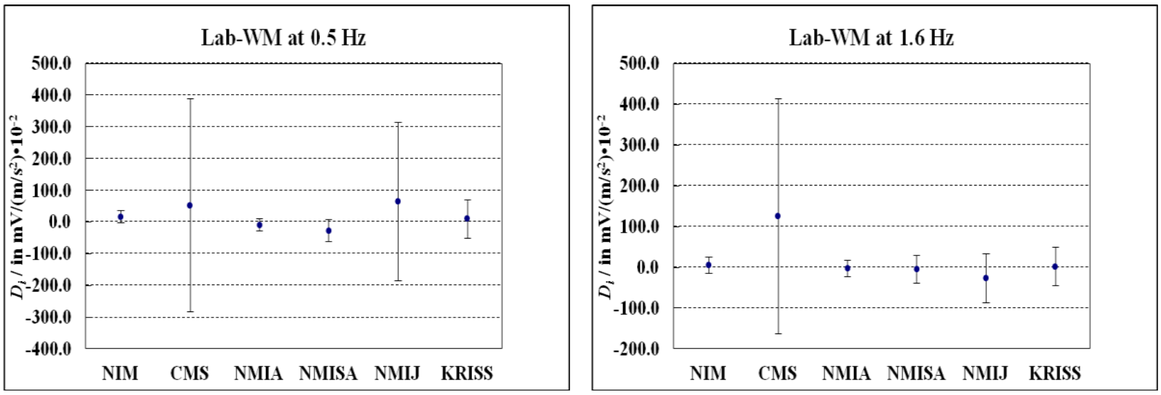


Figure 3: Degree of equivalence for horizontal voltage sensitivities of the SE-1021 at 0.5 Hz and 1.6 Hz with error bars representing the expanded uncertainty (k = 2)

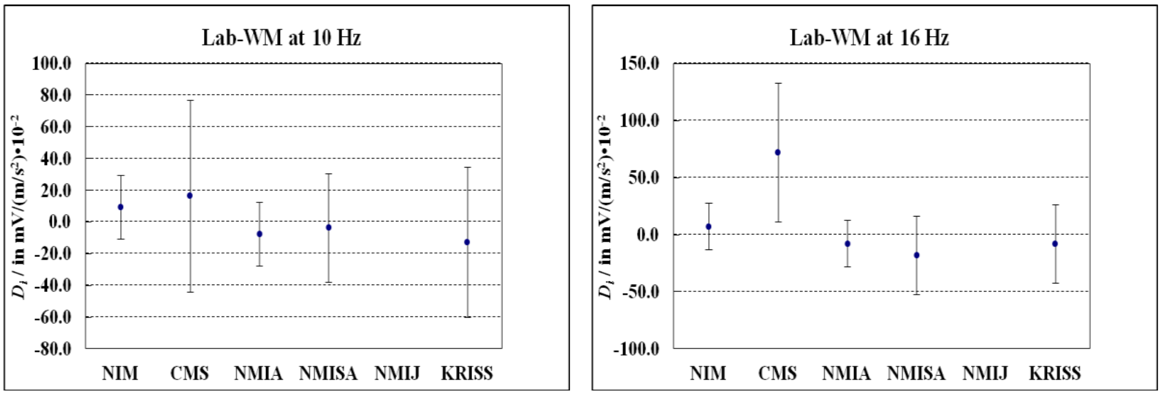


Figure 4: Degree of equivalence for horizontal voltage sensitivities of the SE-1021 at 10 Hz and 16 Hz with error bars representing the expanded uncertainty (k = 2)

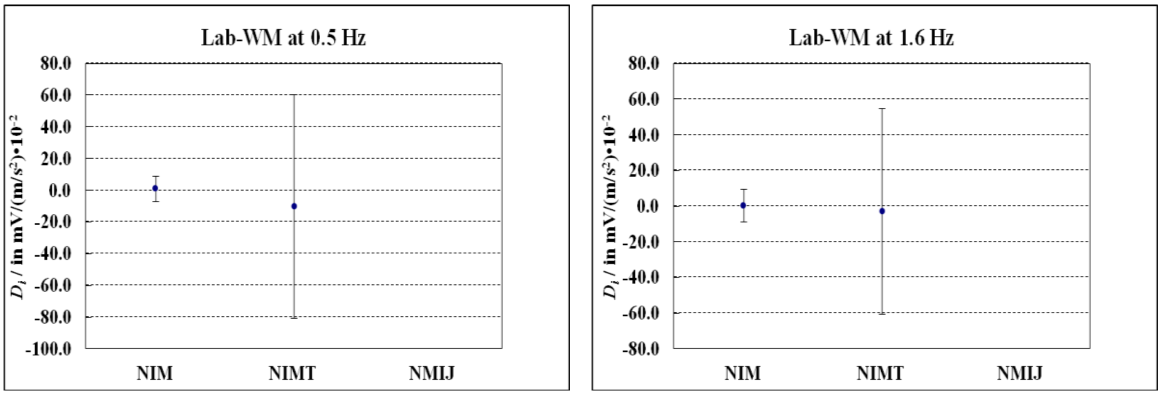


Figure 5: Degree of equivalence for vertical voltage sensitivities of the SE-1021 at 0.5 Hz and 1.6 Hz with error bars representing the expanded uncertainty (k = 2)

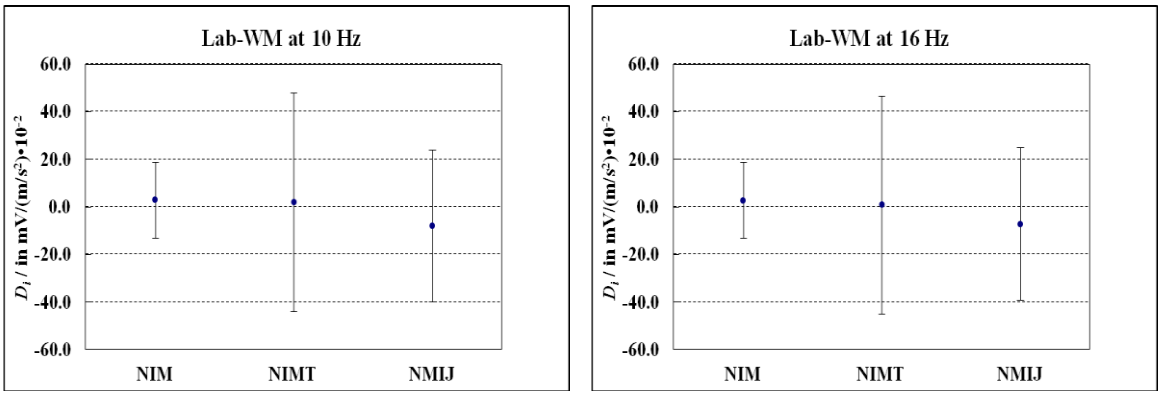


Figure 6: Degree of equivalence for vertical voltage sensitivities of the SE-1021 at 10 Hz and 16 Hz with error bars representing the expanded uncertainty (k = 2)

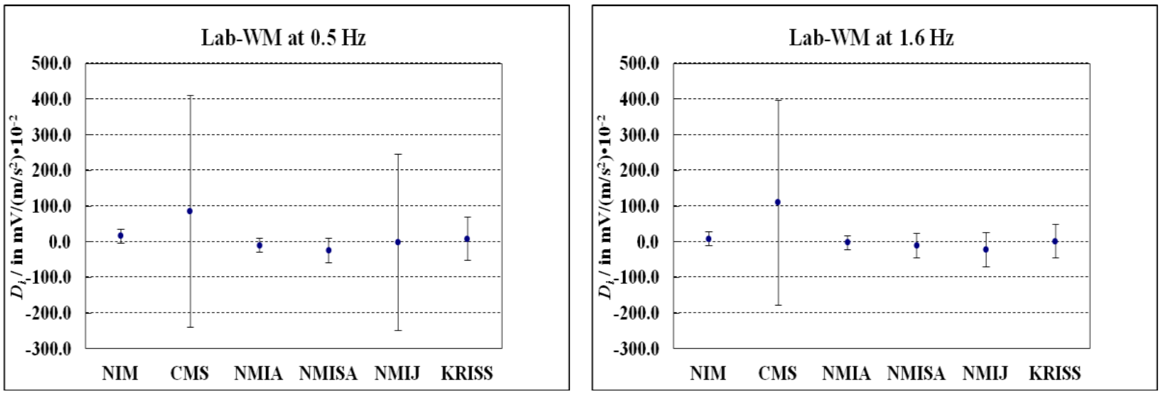


Figure 7: Degree of equivalence for horizontal voltage sensitivities of the SE-1022 at 0.5 Hz and 1.6 Hz with error bars representing the expanded uncertainty (k = 2)

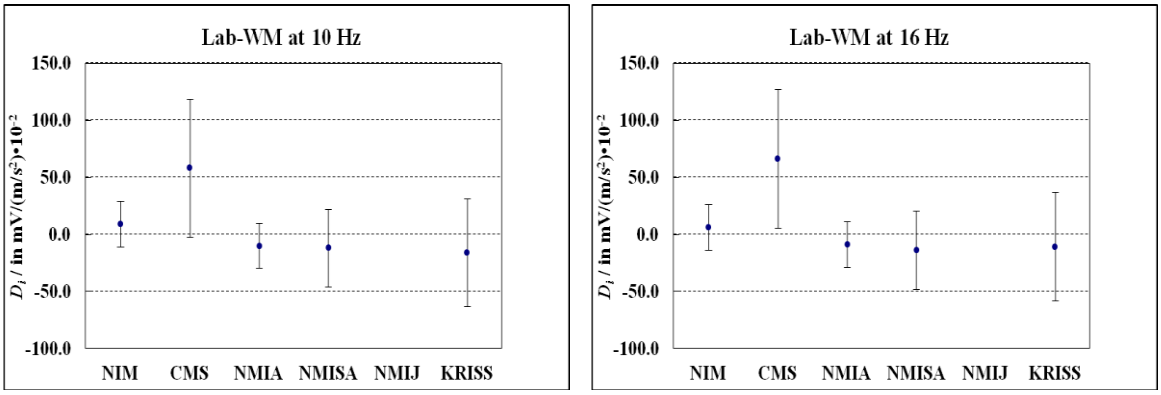


Figure 8: Degree of equivalence for horizontal voltage sensitivities of the SE-1022 at 10 Hz and 16 Hz with error bars representing the expanded uncertainty (k = 2)

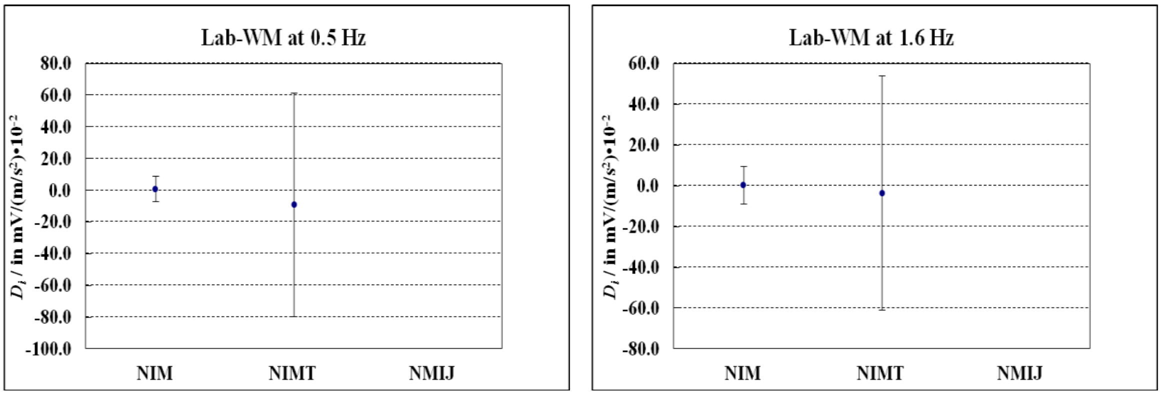
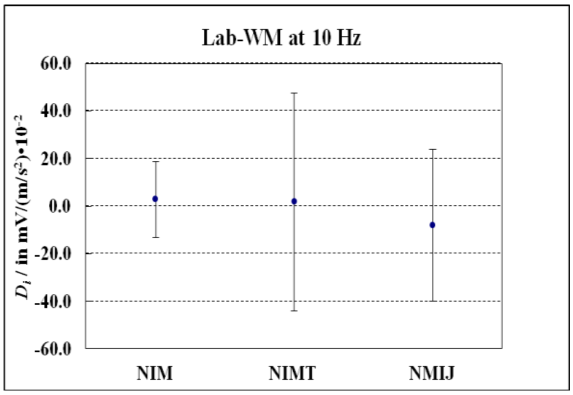


Figure 9: Degree of equivalence for vertical voltage sensitivities of the SE-1022 at 0.5 Hz and 1.6 Hz with error bars representing the expanded uncertainty (k = 2)



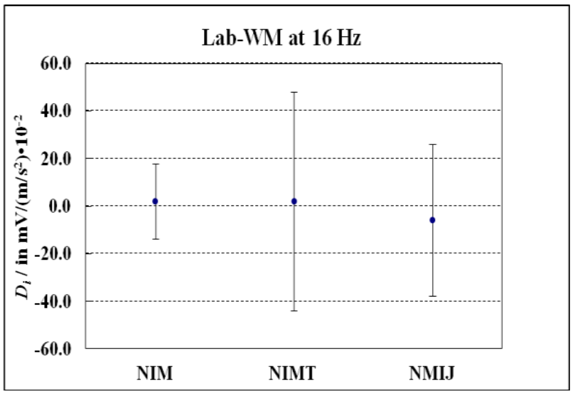


Figure 10: Degree of equivalence for vertical voltage sensitivities of the SE-1022 at 10 Hz and 16 Hz with error bars representing the expanded uncertainty (*k* = 2)

7.4 Degrees of Equivalence between participants

In order to compare the individual results of the participating laboratories of this comparison with one another, the Degree of Equivalence (DoE) of pairs of results with respect to a certain frequency were calculated. These DoEs are each a pair of values of the difference D_{ij} between the respective participants i and j and the combined expanded uncertainty U_{ij} of this difference. These values are calculated for each frequency according to:

$$D_{ij} = x_i - x_j \quad (5)$$

$$U_{ij} = k \cdot \sqrt{u^2(x_i) + u^2(x_j)} \quad (6)$$

with a coverage factor of $k = 2$.

7.4.1 Tables of DoE between participants for horizontal voltage sensitivities of the SE-1021

Table 14: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 0.5 Hz

0.50 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**37.0**	336.9	**-25.0**	27.6	**-43.0**	39.1	**48.0**	249.9	**-6.0**	63.3
CMS	**-37.0**	336.9	-	-	**-62.0**	336.9	**-80.0**	338.0	**11.0**	418.6	**-43.0**	341.7
NMIA	**25.0**	27.6	**62.0**	336.9	-	-	**-18.0**	39.1	**73.0**	249.9	**19.0**	63.3
NMISA	**43.0**	39.1	**80.0**	338.0	**18.0**	39.1	-	-	**91.0**	251.4	**37.0**	69.1
NMIJ	**-48.0**	249.9	**-11.0**	418.6	**-73.0**	249.9	**-91.0**	251.4	-	-	**-54.0**	256.3
KRISS	**6.0**	63.3	**43.0**	341.7	**-19.0**	63.3	**-37.0**	69.1	**54.0**	256.3	-	-

Table 15: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 0.63 Hz

0.63 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**74.0**	337.7	**-19.0**	27.8	**-36.0**	39.2	**-33.0**	99.9	**-3.0**	63.4
CMS	**-74.0**	337.7	-	-	**-93.0**	337.7	**-110.0**	338.9	**-107.0**	351.1	**-77.0**	342.5
NMIA	**19.0**	27.8	**93.0**	337.7	-	-	**-17.0**	39.2	**-14.0**	99.9	**16.0**	63.3
NMISA	**36.0**	39.2	**110.0**	338.9	**17.0**	39.2	-	-	**3.0**	103.7	**33.0**	69.1
NMIJ	**33.0**	99.9	**107.0**	351.1	**14.0**	99.9	**-3.0**	103.7	-	-	**30.0**	115.0
KRISS	**3.0**	63.4	**77.0**	342.5	**-16.0**	63.3	**-33.0**	69.1	**-30.0**	115.0	-	-

Table 16 Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 0.8 Hz

0.8 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**68.0**	300.1	**-17.0**	28.6	**-32.0**	39.8	**-37.0**	100.1	**-9.0**	39.8
CMS	**-68.0**	300.1	**-**	**-**	**-85.0**	300.1	**-100.0**	301.4	**-105.0**	315.0	**-77.0**	301.4
NMIA	**17.0**	28.6	**85.0**	300.1	**-**	**-**	**-15.0**	39.8	**-20.0**	100.1	**8.0**	39.8
NMISA	**32.0**	39.8	**100.0**	301.4	**15.0**	39.8	**-**	**-**	**-5.0**	103.8	**23.0**	48.5
NMIJ	**37.0**	100.1	**105.0**	315.0	**20.0**	100.1	**5.0**	103.8	**-**	**-**	**28.0**	103.9
KRISS	**9.0**	39.8	**77.0**	301.4	**-8.0**	39.8	**-23.0**	48.5	**-28.0**	103.9	**-**	**-**

Table 17: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 1 Hz

1.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**116.0**	288.5	**-10.0**	27.7	**-14.0**	39.2	**-23.0**	112.2	**-1.0**	63.3
CMS	**-116.0**	288.5	**-**	**-**	**-126.0**	288.5	**-130.0**	289.8	**-139.0**	308.3	**-117.0**	294.0
NMIA	**10.0**	27.7	**126.0**	288.5	**-**	**-**	**-4.0**	39.2	**-13.0**	112.2	**9.0**	63.3
NMISA	**14.0**	39.2	**130.0**	289.8	**4.0**	39.2	**-**	**-**	**-9.0**	115.6	**13.0**	69.1
NMIJ	**23.0**	112.2	**139.0**	308.3	**13.0**	112.2	**9.0**	115.6	**-**	**-**	**22.0**	125.8
KRISS	**1.0**	63.3	**117.0**	294.0	**-9.0**	63.3	**-13.0**	69.1	**-22.0**	125.8	**-**	**-**

Table 18: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 1.25 Hz

1.25 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**88.0**	287.9	**-9.0**	28.6	**-12.0**	39.8	**-36.0**	87.8	**-6.0**	39.9
CMS	**-88.0**	287.9	**-**	**-**	**-97.0**	287.9	**-100.0**	289.2	**-124.0**	299.6	**-94.0**	289.2
NMIA	**9.0**	28.6	**97.0**	287.9	**-**	**-**	**-3.0**	39.8	**-27.0**	87.8	**3.0**	39.8
NMISA	**12.0**	39.8	**100.0**	289.2	**3.0**	39.8	**-**	**-**	**-24.0**	92.1	**6.0**	48.5
NMIJ	**36.0**	87.8	**124.0**	299.6	**27.0**	87.8	**24.0**	92.1	**-**	**-**	**30.0**	92.1
KRISS	**6.0**	39.9	**94.0**	289.2	**-3.0**	39.8	**-6.0**	48.5	**-30.0**	92.1	**-**	**-**

Table 19: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 1.6 Hz

1.6 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**119.0**	288.5	**-9.0**	28.3	**-11.0**	39.6	**-32.0**	63.4	**-4.0**	51.5
CMS	**-119.0**	288.5	**-**	**-**	**-128.0**	288.5	**-130.0**	289.8	**-151.0**	294.0	**-123.0**	291.7
NMIA	**9.0**	28.3	**128.0**	288.5	**-**	**-**	**-2.0**	39.6	**-23.0**	63.4	**5.0**	51.5
NMISA	**11.0**	39.6	**130.0**	289.8	**2.0**	39.6	**-**	**-**	**-21.0**	69.2	**7.0**	58.5
NMIJ	**32.0**	63.4	**151.0**	294.0	**23.0**	63.4	**21.0**	69.2	**-**	**-**	**28.0**	76.6
KRISS	**4.0**	51.5	**123.0**	291.7	**-5.0**	51.5	**-7.0**	58.5	**-28.0**	76.6	**-**	**-**

Table 20: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 2 Hz

2.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**57.0**	287.2	**-11.0**	28.6	**-13.0**	39.8	**-25.0**	87.9	**3.0**	39.9
CMS	**-57.0**	287.2	**-**	**-**	**-68.0**	287.2	**-70.0**	288.5	**-82.0**	298.9	**-54.0**	288.5
NMIA	**11.0**	28.6	**68.0**	287.2	**-**	**-**	**-2.0**	39.8	**-14.0**	87.9	**14.0**	39.9
NMISA	**13.0**	39.8	**70.0**	288.5	**2.0**	39.8	**-**	**-**	**-12.0**	92.1	**16.0**	48.6
NMIJ	**25.0**	87.9	**82.0**	298.9	**14.0**	87.9	**12.0**	92.1	**-**	**-**	**28.0**	92.2
KRISS	**-3.0**	39.9	**54.0**	288.5	**-14.0**	39.9	**-16.0**	48.6	**-28.0**	92.2	**-**	**-**

Table 21: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 2.5 Hz

2.5 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**28.0**	274.0	**-11.0**	28.4	**-12.0**	39.7	**-**	**-**	**0.0**	39.7
CMS	**-28.0**	274.0	**-**	**-**	**-39.0**	274.0	**-40.0**	275.4	**-**	**-**	**-28.0**	275.4
NMIA	**11.0**	28.4	**39.0**	274.0	**-**	**-**	**-1.0**	39.7	**-**	**-**	**11.0**	39.7
NMISA	**12.0**	39.7	**40.0**	275.4	**1.0**	39.7	**-**	**-**	**-**	**-**	**12.0**	48.4
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**0.0**	39.7	**28.0**	275.4	**-11.0**	39.7	**-12.0**	48.4	**-**	**-**	**-**	**-**

Table 22: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 3.15 Hz

3.15 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**28.0**	63.9	**-11.0**	28.8	**-22.0**	39.9	-	-	**-9.0**	40.0
CMS	**-28.0**	63.9	-	-	**-39.0**	63.9	**-50.0**	69.6	-	-	**-37.0**	69.6
NMIA	**11.0**	28.8	**39.0**	63.9	-	-	**-11.0**	39.9	-	-	**2.0**	39.9
NMISA	**22.0**	39.9	**50.0**	69.6	**11.0**	39.9	-	-	-	-	**13.0**	48.6
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**9.0**	40.0	**37.0**	69.6	**-2.0**	39.9	**-13.0**	48.6	-	-	-	-

Table 23: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 4 Hz

4.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**67.0**	64.1	**-12.0**	28.8	**-13.0**	40.0	-	-	**-12.0**	40.0
CMS	**-67.0**	64.1	-	-	**-79.0**	64.1	**-80.0**	69.8	-	-	**-79.0**	69.8
NMIA	**12.0**	28.8	**79.0**	64.1	-	-	**-1.0**	39.9	-	-	**0.0**	39.9
NMISA	**13.0**	40.0	**80.0**	69.8	**1.0**	39.9	-	-	-	-	**1.0**	48.6
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**12.0**	40.0	**79.0**	69.8	**0.0**	39.9	**-1.0**	48.6	-	-	-	-

Table 24: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 5 Hz

5.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**–**	–	**26.0**	63.9	**-13.0**	28.8	**-14.0**	40.0	**–**	–	**-9.0**	40.0
CMS	**-26.0**	63.9	**–**	–	**-39.0**	63.9	**-40.0**	69.6	**–**	–	**-35.0**	69.6
NMIA	**13.0**	28.8	**39.0**	63.9	**–**	–	**-1.0**	39.9	**–**	–	**4.0**	39.9
NMISA	**14.0**	40.0	**40.0**	69.6	**1.0**	39.9	**–**	–	**–**	–	**5.0**	48.6
NMIJ	**–**	–	**–**	–	**–**	–	**–**	–	**–**	–	**–**	–
KRISS	**9.0**	40.0	**35.0**	69.6	**-4.0**	39.9	**-5.0**	48.6	**–**	–	**–**	–

Table 25: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 6.3 Hz

6.3 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**–**	–	**46.0**	64.0	**-12.0**	28.8	**-14.0**	40.0	**–**	–	**-17.0**	39.9
CMS	**-46.0**	64.0	**–**	–	**-58.0**	64.0	**-60.0**	69.7	**–**	–	**-63.0**	69.7
NMIA	**12.0**	28.8	**58.0**	64.0	**–**	–	**-2.0**	39.9	**–**	–	**-5.0**	39.9
NMISA	**14.0**	40.0	**60.0**	69.7	**2.0**	39.9	**–**	–	**–**	–	**-3.0**	48.6
NMIJ	**–**	–	**–**	–	**–**	–	**–**	–	**–**	–	**–**	–
KRISS	**17.0**	39.9	**63.0**	69.7	**5.0**	39.9	**3.0**	48.6	**–**	–	**–**	–

Table 26: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 8 Hz

8.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**44.0**	63.8	**-13.0**	28.3	**-16.0**	39.6	**-**	**-**	**-18.0**	51.4
CMS	**-44.0**	63.8	**-**	**-**	**-57.0**	63.8	**-60.0**	69.5	**-**	**-**	**-62.0**	76.9
NMIA	**13.0**	28.3	**57.0**	63.8	**-**	**-**	**-3.0**	39.6	**-**	**-**	**-5.0**	51.4
NMISA	**16.0**	39.6	**60.0**	69.5	**3.0**	39.6	**-**	**-**	**-**	**-**	**-2.0**	58.4
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**18.0**	51.4	**62.0**	76.9	**5.0**	51.4	**2.0**	58.4	**-**	**-**	**-**	**-**

Table 27: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 10 Hz

10.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**7.0**	63.6	**-17.0**	28.3	**-13.0**	39.6	**-**	**-**	**-22.0**	51.4
CMS	**-7.0**	63.6	**-**	**-**	**-24.0**	63.6	**-20.0**	69.4	**-**	**-**	**-29.0**	76.8
NMIA	**17.0**	28.3	**24.0**	63.6	**-**	**-**	**4.0**	39.6	**-**	**-**	**-5.0**	51.4
NMISA	**13.0**	39.6	**20.0**	69.4	**-4.0**	39.6	**-**	**-**	**-**	**-**	**-9.0**	58.4
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**22.0**	51.4	**29.0**	76.8	**5.0**	51.4	**9.0**	58.4	**-**	**-**	**-**	**-**

Table 28: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 12.5 Hz

12.5 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**55.0**	51.9	**-14.0**	28.5	**-15.0**	39.8	-	-	**-20.0**	51.6
CMS	**-55.0**	51.9	-	-	**-69.0**	51.8	**-70.0**	58.8	-	-	**-75.0**	67.3
NMIA	**14.0**	28.5	**69.0**	51.8	-	-	**-1.0**	39.8	-	-	**-6.0**	51.6
NMISA	**15.0**	39.8	**70.0**	58.8	**1.0**	39.8	-	-	-	-	**-5.0**	58.6
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**20.0**	51.6	**75.0**	67.3	**6.0**	51.6	**5.0**	58.6	-	-	-	-

Table 29: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 16 Hz

16.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**65.0**	64.2	**-15.0**	28.8	**-25.0**	40.0	-	-	**-15.0**	40.0
CMS	**-65.0**	64.2	-	-	**-80.0**	64.2	**-90.0**	69.9	-	-	**-80.0**	69.9
NMIA	**15.0**	28.8	**80.0**	64.2	-	-	**-10.0**	40.0	-	-	**0.0**	40.0
NMISA	**25.0**	40.0	**90.0**	69.9	**10.0**	40.0	-	-	-	-	**10.0**	48.7
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**15.0**	40.0	**80.0**	69.9	**0.0**	40.0	**-10.0**	48.7	-	-	-	-

Table 30: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1021 at 20 Hz

20.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i \rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j \downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**40.0**	64.1	**-17.0**	28.8	**-20.0**	40.1	-	-	**-23.0**	40.0
CMS	**-40.0**	64.1	-	-	**-57.0**	64.1	**-60.0**	69.9	-	-	**-63.0**	69.9
NMIA	**17.0**	28.8	**57.0**	64.1	-	-	**-3.0**	40.0	-	-	**-6.0**	40.0
NMISA	**20.0**	40.1	**60.0**	69.9	**3.0**	40.0	-	-	-	-	**-3.0**	48.7
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**23.0**	40.0	**63.0**	69.9	**6.0**	40.0	**3.0**	48.7	-	-	-	-

7.4.2 Tables of DoE between participants for vertical voltage sensitivities of the SE-1021

Table 31: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 0.5 Hz

0.50 Hz	NIM		NIMT		NMIJ	
$i \rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j \downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-11.0**	71.0	-	-
NIMT	**11.0**	71.0	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 32: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 0.63 Hz

0.63 Hz	NIM		NIMT		NMIJ	
$i \rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j \downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-10.0**	71.0	-	-
NIMT	**10.0**	71.0	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 33: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 0.8 Hz

0.8 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-9.0**	71.0	-	-
NIMT	**9.0**	71.0	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 34: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 1 Hz

1.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-4.0**	58.3	-	-
NIMT	**4.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 35: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 1.25 Hz

1.25 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-3.0**	58.3	-	-
NIMT	**3.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 36: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 1.6 Hz

1.6 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-3.0**	58.3	-	-
NIMT	**3.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 37: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 2 Hz

2.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-4.0**	58.3	-	-
NIMT	**4.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 38: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 2.5 Hz

2.5 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-5.0**	60.8	**-25.0**	35.1
NIMT	**5.0**	60.8	-	-	**-20.0**	66.8
NMIJ	**25.0**	35.1	**20.0**	66.8	-	-

Table 39: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 3.15 Hz

3.15 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-5.0**	60.8	**-20.0**	35.1
NIMT	**5.0**	60.8	**-**	**-**	**-15.0**	66.8
NMIJ	**20.0**	35.1	**15.0**	66.8	**-**	**-**

Table 40: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 4 Hz

4.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-4.0**	60.8	**-17.0**	35.1
NIMT	**4.0**	60.8	**-**	**-**	**-13.0**	66.8
NMIJ	**17.0**	35.1	**13.0**	66.8	**-**	**-**

Table 41: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 5 Hz

5.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-2.0**	48.5	**-17.0**	35.7
NIMT	**2.0**	48.5	**-**	**-**	**-15.0**	55.9
NMIJ	**17.0**	35.7	**15.0**	55.9	**-**	**-**

Table 42: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 6.3 Hz

6.3 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-1.0**	48.5	**-13.0**	35.7
NIMT	**1.0**	48.5	**-**	**-**	**-12.0**	55.9
NMIJ	**13.0**	35.7	**12.0**	55.9	**-**	**-**

Table 43: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 8 Hz

8.0 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-2.0**	48.5	**-13.0**	35.7
NIMT	**2.0**	48.5	**-**	**-**	**-11.0**	55.9
NMIJ	**13.0**	35.7	**11.0**	55.9	**-**	**-**

Table 44: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 10 Hz

10.0 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-1.0**	48.5	**-11.0**	35.7
NIMT	**1.0**	48.5	**-**	**-**	**-10.0**	55.9
NMIJ	**11.0**	35.7	**10.0**	55.9	**-**	**-**

Table 45: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 12.5 Hz

12.5 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**0.0**	48.6	**-9.0**	35.7
NIMT	**0.0**	48.6	-	-	**-9.0**	55.9
NMIJ	**9.0**	35.7	**9.0**	55.9	-	-

Table 46: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 16 Hz

16.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-2.0**	48.6	**-10.0**	35.7
NIMT	**2.0**	48.6	-	-	**-8.0**	56.0
NMIJ	**10.0**	35.7	**8.0**	56.0	-	-

Table 47: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1021 at 20 Hz

20.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-1.0**	48.6	**-8.0**	35.8
NIMT	**1.0**	48.6	-	-	**-7.0**	56.0
NMIJ	**8.0**	35.8	**7.0**	56.0	-	-

7.4.3 Tables of DoE between participants for horizontal voltage sensitivities of the SE-1022

Table 48: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 0.5 Hz

0.50 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**70.0**	325.0	**-26.0**	27.6	**-40.0**	39.1	**-18.0**	248.3	**-8.0**	63.2
CMS	**-70.0**	325.0	-	-	**-96.0**	325.0	**-110.0**	326.1	**-88.0**	408.1	**-78.0**	329.9
NMIA	**26.0**	27.6	**96.0**	325.0	-	-	**-14.0**	39.0	**8.0**	248.3	**18.0**	63.2
NMISA	**40.0**	39.1	**110.0**	326.1	**14.0**	39.0	-	-	**22.0**	249.9	**32.0**	69.0
NMIJ	**18.0**	248.3	**88.0**	408.1	**-8.0**	248.3	**-22.0**	249.9	-	-	**10.0**	254.8
KRISS	**8.0**	63.2	**78.0**	329.9	**-18.0**	63.2	**-32.0**	69.0	**-10.0**	254.8	-	-

Table 49: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 0.63 Hz

0.63 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**77.0**	337.5	**-20.0**	27.8	**-33.0**	39.2	**-50.0**	87.5	**-12.0**	63.3
CMS	**-77.0**	337.5	-	-	**-97.0**	337.5	**-110.0**	338.6	**-127.0**	347.5	**-89.0**	342.2
NMIA	**20.0**	27.8	**97.0**	337.5	-	-	**-13.0**	39.2	**-30.0**	87.4	**8.0**	63.3
NMISA	**33.0**	39.2	**110.0**	338.6	**13.0**	39.2	-	-	**-17.0**	91.7	**21.0**	69.0
NMIJ	**50.0**	87.5	**127.0**	347.5	**30.0**	87.4	**17.0**	91.7	-	-	**38.0**	104.3
KRISS	**12.0**	63.3	**89.0**	342.2	**-8.0**	63.3	**-21.0**	69.0	**-38.0**	104.3	-	-

Table 50: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 0.8 Hz

0.8 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**71.0**	312.3	**-18.0**	28.5	**-29.0**	39.7	**-28.0**	100.1	**-12.0**	39.8
CMS	**-71.0**	312.3	**-**	**-**	**-89.0**	312.3	**-100.0**	313.5	**-99.0**	326.7	**-83.0**	313.5
NMIA	**18.0**	28.5	**89.0**	312.3	**-**	**-**	**-11.0**	39.7	**-10.0**	100.0	**6.0**	39.8
NMISA	**29.0**	39.7	**100.0**	313.5	**11.0**	39.7	**-**	**-**	**1.0**	103.8	**17.0**	48.4
NMIJ	**28.0**	100.1	**99.0**	326.7	**10.0**	100.0	**-1.0**	103.8	**-**	**-**	**16.0**	103.8
KRISS	**12.0**	39.8	**83.0**	313.5	**-6.0**	39.8	**-17.0**	48.4	**-16.0**	103.8	**-**	**-**

Table 51: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 1 Hz

1.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**109.0**	288.0	**-11.0**	28.0	**-21.0**	39.3	**-28.0**	124.4	**-7.0**	51.2
CMS	**-109.0**	288.0	**-**	**-**	**-120.0**	288.0	**-130.0**	289.3	**-137.0**	312.5	**-116.0**	291.2
NMIA	**11.0**	28.0	**120.0**	288.0	**-**	**-**	**-10.0**	39.3	**-17.0**	124.4	**4.0**	51.2
NMISA	**21.0**	39.3	**130.0**	289.3	**10.0**	39.3	**-**	**-**	**-7.0**	127.4	**14.0**	58.2
NMIJ	**28.0**	124.4	**137.0**	312.5	**17.0**	124.4	**7.0**	127.4	**-**	**-**	**21.0**	131.6
KRISS	**7.0**	51.2	**116.0**	291.2	**-4.0**	51.2	**-14.0**	58.2	**-21.0**	131.6	**-**	**-**

Table 52: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 1.25 Hz

1.25 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**83.0**	287.3	**-8.0**	28.1	**-17.0**	39.4	**-30.0**	87.6	**-7.0**	51.3
CMS	**-83.0**	287.3	**-**	**-**	**-91.0**	287.3	**-100.0**	288.7	**-113.0**	299.1	**-90.0**	290.5
NMIA	**8.0**	28.1	**91.0**	287.3	**-**	**-**	**-9.0**	39.4	**-22.0**	87.6	**1.0**	51.3
NMISA	**17.0**	39.4	**100.0**	288.7	**9.0**	39.4	**-**	**-**	**-13.0**	91.8	**10.0**	58.3
NMIJ	**30.0**	87.6	**113.0**	299.1	**22.0**	87.6	**13.0**	91.8	**-**	**-**	**23.0**	97.5
KRISS	**7.0**	51.3	**90.0**	290.5	**-1.0**	51.3	**-10.0**	58.3	**-23.0**	97.5	**-**	**-**

Table 53: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 1.6 Hz

1.6 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**101.0**	287.8	**-11.0**	28.5	**-19.0**	39.7	**-31.0**	51.4	**-7.0**	51.5
CMS	**-101.0**	287.8	**-**	**-**	**-112.0**	287.8	**-120.0**	289.2	**-132.0**	291.0	**-108.0**	291.0
NMIA	**11.0**	28.5	**112.0**	287.8	**-**	**-**	**-8.0**	39.7	**-20.0**	51.4	**4.0**	51.5
NMISA	**19.0**	39.7	**120.0**	289.2	**8.0**	39.7	**-**	**-**	**-12.0**	58.4	**12.0**	58.5
NMIJ	**31.0**	51.4	**132.0**	291.0	**20.0**	51.4	**12.0**	58.4	**-**	**-**	**24.0**	67.0
KRISS	**7.0**	51.5	**108.0**	291.0	**-4.0**	51.5	**-12.0**	58.5	**-24.0**	67.0	**-**	**-**

Table 54: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 2 Hz

2.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**71.0**	287.2	**-11.0**	28.6	**-19.0**	39.8	**-43.0**	87.7	**2.0**	39.8
CMS	**-71.0**	287.2	**-**	**-**	**-82.0**	287.2	**-90.0**	288.5	**-114.0**	298.9	**-69.0**	288.5
NMIA	**11.0**	28.6	**82.0**	287.2	**-**	**-**	**-8.0**	39.8	**-32.0**	87.6	**13.0**	39.8
NMISA	**19.0**	39.8	**90.0**	288.5	**8.0**	39.8	**-**	**-**	**-24.0**	91.9	**21.0**	48.5
NMIJ	**43.0**	87.7	**114.0**	298.9	**32.0**	87.6	**24.0**	91.9	**-**	**-**	**45.0**	91.9
KRISS	**-2.0**	39.8	**69.0**	288.5	**-13.0**	39.8	**-21.0**	48.5	**-45.0**	91.9	**-**	**-**

Table 55: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 2.5 Hz

2.5 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**31.0**	273.8	**-12.0**	28.4	**-19.0**	39.6	**-**	**-**	**0.0**	39.7
CMS	**-31.0**	273.8	**-**	**-**	**-43.0**	273.8	**-50.0**	275.2	**-**	**-**	**-31.0**	275.2
NMIA	**12.0**	28.4	**43.0**	273.8	**-**	**-**	**-7.0**	39.6	**-**	**-**	**12.0**	39.7
NMISA	**19.0**	39.6	**50.0**	275.2	**7.0**	39.6	**-**	**-**	**-**	**-**	**19.0**	48.4
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**0.0**	39.7	**31.0**	275.2	**-12.0**	39.7	**-19.0**	48.4	**-**	**-**	**-**	**-**

Table 56: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 3.15 Hz

3.15 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**90.0**	76.3	**-13.0**	28.6	**-10.0**	39.8	-	-	**-10.0**	39.8
CMS	**-90.0**	76.3	-	-	**-103.0**	76.3	**-100.0**	81.2	-	-	**-100.0**	81.2
NMIA	**13.0**	28.6	**103.0**	76.3	-	-	**3.0**	39.8	-	-	**3.0**	39.8
NMISA	**10.0**	39.8	**100.0**	81.2	**-3.0**	39.8	-	-	-	-	**0.0**	48.5
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**10.0**	39.8	**100.0**	81.2	**-3.0**	39.8	**0.0**	48.5	-	-	-	-

Table 57: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 4 Hz

4.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**70.0**	76.2	**-13.0**	28.6	**-20.0**	39.8	-	-	**-14.0**	39.8
CMS	**-70.0**	76.2	-	-	**-83.0**	76.2	**-90.0**	81.0	-	-	**-84.0**	81.1
NMIA	**13.0**	28.6	**83.0**	76.2	-	-	**-7.0**	39.8	-	-	**-1.0**	39.8
NMISA	**20.0**	39.8	**90.0**	81.0	**7.0**	39.8	-	-	-	-	**6.0**	48.5
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**14.0**	39.8	**84.0**	81.1	**1.0**	39.8	**-6.0**	48.5	-	-	-	-

Table 58: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 5 Hz

5.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**9.0**	63.7	**-14.0**	28.7	**-11.0**	39.9	**-**	**-**	**-18.0**	39.9
CMS	**-9.0**	63.7	**-**	**-**	**-23.0**	63.7	**-20.0**	69.5	**-**	**-**	**-27.0**	69.5
NMIA	**14.0**	28.7	**23.0**	63.7	**-**	**-**	**3.0**	39.9	**-**	**-**	**-4.0**	39.9
NMISA	**11.0**	39.9	**20.0**	69.5	**-3.0**	39.9	**-**	**-**	**-**	**-**	**-7.0**	48.6
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**18.0**	39.9	**27.0**	69.5	**4.0**	39.9	**7.0**	48.6	**-**	**-**	**-**	**-**

Table 59: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 6.3 Hz

6.3 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**9.0**	63.7	**-14.0**	28.7	**-11.0**	39.9	**-**	**-**	**-21.0**	39.9
CMS	**-9.0**	63.7	**-**	**-**	**-23.0**	63.7	**-20.0**	69.5	**-**	**-**	**-30.0**	69.5
NMIA	**14.0**	28.7	**23.0**	63.7	**-**	**-**	**3.0**	39.9	**-**	**-**	**-7.0**	39.9
NMISA	**11.0**	39.9	**20.0**	69.5	**-3.0**	39.9	**-**	**-**	**-**	**-**	**-10.0**	48.6
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**21.0**	39.9	**30.0**	69.5	**7.0**	39.9	**10.0**	48.6	**-**	**-**	**-**	**-**

Table 60: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 8 Hz

8.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i \rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j \downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**16.0**	63.6	**-15.0**	28.3	**-14.0**	39.6	-	-	**-22.0**	51.4
CMS	**-16.0**	63.6	-	-	**-31.0**	63.6	**-30.0**	69.3	-	-	**-38.0**	76.7
NMIA	**15.0**	28.3	**31.0**	63.6	-	-	**1.0**	39.6	-	-	**-7.0**	51.3
NMISA	**14.0**	39.6	**30.0**	69.3	**-1.0**	39.6	-	-	-	-	**-8.0**	58.3
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**22.0**	51.4	**38.0**	76.7	**7.0**	51.3	**8.0**	58.3	-	-	-	-

Table 61: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 10 Hz

10.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i \rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j \downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**49.0**	63.8	**-19.0**	28.3	**-21.0**	39.6	-	-	**-25.0**	51.4
CMS	**-49.0**	63.8	-	-	**-68.0**	63.8	**-70.0**	69.5	-	-	**-74.0**	76.8
NMIA	**19.0**	28.3	**68.0**	63.8	-	-	**-2.0**	39.6	-	-	**-6.0**	51.4
NMISA	**21.0**	39.6	**70.0**	69.5	**2.0**	39.6	-	-	-	-	**-4.0**	58.4
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**25.0**	51.4	**74.0**	76.8	**6.0**	51.4	**4.0**	58.4	-	-	-	-

Table 62: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 12.5 Hz

12.5 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**29.0**	63.7	**-15.0**	28.3	**-21.0**	39.6	-	-	**-22.0**	51.4
CMS	**-29.0**	63.7	-	-	**-44.0**	63.7	**-50.0**	69.4	-	-	**-51.0**	76.8
NMIA	**15.0**	28.3	**44.0**	63.7	-	-	**-6.0**	39.6	-	-	**-7.0**	51.4
NMISA	**21.0**	39.6	**50.0**	69.4	**6.0**	39.6	-	-	-	-	**-1.0**	58.4
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**22.0**	51.4	**51.0**	76.8	**7.0**	51.4	**1.0**	58.4	-	-	-	-

Table 63: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 16 Hz

16.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**60.0**	63.9	**-15.0**	28.3	**-20.0**	39.6	-	-	**-17.0**	51.4
CMS	**-60.0**	63.9	-	-	**-75.0**	63.9	**-80.0**	69.6	-	-	**-77.0**	77.0
NMIA	**15.0**	28.3	**75.0**	63.9	-	-	**-5.0**	39.6	-	-	**-2.0**	51.4
NMISA	**20.0**	39.6	**80.0**	69.6	**5.0**	39.6	-	-	-	-	**3.0**	58.4
NMIJ	-	-	-	-	-	-	-	-	-	-	-	-
KRISS	**17.0**	51.4	**77.0**	77.0	**2.0**	51.4	**-3.0**	58.4	-	-	-	-

Table 64: Degrees of equivalence between the participants for horizontal voltage sensitivities of the SE-1022 at 20 Hz

20.0 Hz	NIM		CMS		NMIA		NMISA		NMIJ		KRISS	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**26.0**	63.8	**-18.0**	28.3	**-24.0**	39.6	**-**	**-**	**-25.0**	51.5
CMS	**-26.0**	63.8	**-**	**-**	**-44.0**	63.8	**-50.0**	69.5	**-**	**-**	**-51.0**	76.9
NMIA	**18.0**	28.3	**44.0**	63.8	**-**	**-**	**-6.0**	39.6	**-**	**-**	**-7.0**	51.5
NMISA	**24.0**	39.6	**50.0**	69.5	**6.0**	39.6	**-**	**-**	**-**	**-**	**-1.0**	58.5
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
KRISS	**25.0**	51.5	**51.0**	76.9	**7.0**	51.5	**1.0**	58.5	**-**	**-**	**-**	**-**

7.4.4 Tables of DoE between participants for vertical voltage sensitivities of the SE-1022

Table 65: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 0.5 Hz

0.50 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-10.0**	71.0	**-**	**-**
NIMT	**10.0**	71.0	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 66: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 0.63 Hz

0.63 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-12.0**	71.0	**-**	**-**
NIMT	**12.0**	71.0	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 67: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 0.8 Hz

0.8 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-12.0**	71.0	**-**	**-**
NIMT	**12.0**	71.0	**-**	**-**	**-**	**-**
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**

Table 68: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 1 Hz

1.0 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-6.0**	58.3	**-**	**-**
NIMT	**6.0**	58.3	**-**	**-**	**-**	**-**
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**

Table 69: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 1.25 Hz

1.25 Hz	NIM		NIMT		NMIJ	
i→	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
j↓	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-4.0**	58.3	**-**	**-**
NIMT	**4.0**	58.3	**-**	**-**	**-**	**-**
NMIJ	**-**	**-**	**-**	**-**	**-**	**-**

Table 70: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 1.6 Hz

1.6 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-4.0**	58.3	-	-
NIMT	**4.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 71: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 2 Hz

2.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-5.0**	58.3	-	-
NIMT	**5.0**	58.3	-	-	-	-
NMIJ	-	-	-	-	-	-

Table 72: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 2.5 Hz

2.5 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-5.0**	60.7	**-27.0**	35.0
NIMT	**5.0**	60.7	-	-	**-22.0**	66.7
NMIJ	**27.0**	35.0	**22.0**	66.7	-	-

Table 73: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 3.15 Hz

3.15 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-5.0**	60.7	**-21.0**	35.0
NIMT	**5.0**	60.7	**-**	**-**	**-16.0**	66.7
NMIJ	**21.0**	35.0	**16.0**	66.7	**-**	**-**

Table 74: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 4 Hz

4.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-5.0**	60.7	**-19.0**	35.1
NIMT	**5.0**	60.7	**-**	**-**	**-14.0**	66.7
NMIJ	**19.0**	35.1	**14.0**	66.7	**-**	**-**

Table 75: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 5 Hz

5.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	**-**	**-3.0**	48.5	**-17.0**	35.6
NIMT	**3.0**	48.5	**-**	**-**	**-14.0**	55.8
NMIJ	**17.0**	35.6	**14.0**	55.8	**-**	**-**

Table 76: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 6.3 Hz

6.3 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-2.0**	48.5	**-14.0**	35.6
NIMT	**2.0**	48.5	-	-	**-12.0**	55.8
NMIJ	**14.0**	35.6	**12.0**	55.8	-	-

Table 77: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 8 Hz

8.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-2.0**	48.5	**-12.0**	35.6
NIMT	**2.0**	48.5	-	-	**-10.0**	55.8
NMIJ	**12.0**	35.6	**10.0**	55.8	-	-

Table 78: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 10 Hz

10.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	-	-	**-1.0**	48.5	**-11.0**	35.7
NIMT	**1.0**	48.5	-	-	**-10.0**	55.8
NMIJ	**11.0**	35.7	**10.0**	55.8	-	-

Table 79: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 12.5 Hz

12.5 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	-	**-2.0**	48.5	**-10.0**	35.7
NIMT	**2.0**	48.5	**-**	-	**-8.0**	55.8
NMIJ	**10.0**	35.7	**8.0**	55.8	**-**	-

Table 80: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 16 Hz

16.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	-	**0.0**	48.5	**-8.0**	35.7
NIMT	**0.0**	48.5	**-**	-	**-8.0**	55.9
NMIJ	**8.0**	35.7	**8.0**	55.9	**-**	-

Table 81: Degrees of equivalence between the participants for vertical voltage sensitivities of the SE-1022 at 20 Hz

20.0 Hz	NIM		NIMT		NMIJ	
$i\rightarrow$	D_{ij}	U_{ij}	D_{ij}	U_{ij}	D_{ij}	U_{ij}
$j\downarrow$	(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})		(mV/(m/s^2)•10^{-2})	
NIM	**-**	-	**1.0**	48.6	**-7.0**	35.7
NIMT	**-1.0**	48.6	**-**	-	**-8.0**	55.9
NMIJ	**7.0**	35.7	**8.0**	55.9	**-**	-

8 Conclusion

Seven NMIs measured the voltage sensitivity of two accelerometer standard sets (one set included a quartz-flexure servo accelerometer of single-ended type and a signal conditioner) at 17 frequencies from 0.5 Hz to 20 Hz, in either horizontal or vertical installation direction, except that the pilot laboratory did both directions. The results of the APMP.AUV.V-K3 are four sets of KCRVs, their uncertainties and degrees of equivalence illustrating the performance of the participant laboratories with respect to one another.

The calibration results obtained for the accelerometers represent the current calibration capabilities of the participating laboratories for the voltage sensitivity of single-ended accelerometers. At the reference frequency of 1.6 Hz (specified in ISO 16063-11:1999), the participating laboratories calibrated the transfer standard sets with their claimed relative expanded uncertainty (k = 2), the smallest of which equal to 0.2%, i.e. smaller than the limit specified by the ISO standard [4].

In conclusion, the degrees of equivalence calculated from the data submitted by the seven laboratories, support the uncertainty of measurement reported by the seven laboratories for the calibration of the magnitude of the complex sensitivities of accelerometer over the frequency range 0.5 Hz to 20 Hz, with the only exception of CMS at 3.15Hz, 4Hz, 12.5Hz and 16Hz. The completion of APMP.AUV.V-K3 can serve as part of the basis for a planned key comparison targeted at a low-frequency range at CC level.

9 Bibliography

[1] von Martens, H.-J. et al., Final report on key comparison CCAUV.V-K1, 2003, Metrologia, 40, Tech. Suppl. 09001.

[2] Guidelines for CIPM key comparisons (Appendix F to the "Mutual recognition of national measurements standards and of measurement certificates issued by national metrology institutes" (MRA)). March 1, 1999.

[3] Technical Protocol of the APMP Key comparison APMP.AUV.V-K3 (Vibration). NIM, Qiao SUN, December 2010.

[4] ISO 16063-11:1999 "Methods for the calibration of vibration and shock transducers - Part 11: Primary vibration calibration by laser interferometry" .

[5] ISO/IEC Guide 98-3:2008 "Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement" (GUM: 1995).

[6] ISO/IEC Guide 98-3:2008 "Suppl. 1:2008 Propagation of distributions using a Monte Carlo method".

Appendix A: Technical Protocol

National Institute of Metrology (NIM)

December 10th, 2010 (participants revised)

Mr. Qiao SUN

Technical Protocol of the APMP Key Comparison APMP.AUV.V-K3

1 Task and Purpose of the Comparison

According to the rules set up by the CIPM MRA the consultative committees of the CIPM have the responsibility to establish ‘degrees of equivalence’ (DoE) between the different measurement standards operated by the national NMIs. This is done by conducting key comparisons (KC) on different levels of the international metrological infrastructure. The previous top level KC in the field of Vibration metrology, CCAUV.V-K1 was completed in the year 2001 in the frequency range from 40 Hz to 5 kHz. The ongoing CCAUV.V-K2 is aimed at frequency range from 10 Hz to 10 kHz.

However, recent developments in technology and improvements at the NMIs have extended the low-frequency vibration limit of calibration capabilities down to 0.5 Hz and even 0.1 Hz. Therefore during the meeting of APMP TCAUV in 2008, the decision was taken to make preparations for a further comparison targeted at a low-frequency range.

In the field of vibration, this regional key comparison is organized in order to compare measurements of sinusoidal linear accelerations in the frequency range from 0.5 Hz to 20 Hz. Moreover, the magnitude of the complex sensitivity calibration and measurement capabilities (CMCs) of the participating laboratories for accelerometer calibration are to be examined and compared. It is the task of the comparison to measure the magnitude of the complex sensitivity of two accelerometer standard sets (one set including a quartz-flexure servo accelerometer of single-ended type and a signal conditioner) at different frequencies with acceleration amplitudes as specified in section 3. The results of this APMP Comparison will, after approval by CCAUV, serve as the foundation at low vibration frequency for the registration of ‘calibration and measurement capabilities’ (CMC) in the framework of the CIPM MRA.

The voltage sensitivity is calculated as the ratio of the amplitude of the accelerometer standard set output voltage to the amplitude of the acceleration at its reference surface. The magnitude of the complex voltage sensitivity shall be given in milli volt per meter per second squared (mV/(m/s²)) for the different measurement conditions specified in section 4.

For the calibration of the accelerometer standard sets, laser interferometry in compliance with method 1 or method 3 of the international standard ISO 16063-11:1999 has to be applied, in order to cover the entire frequency range.

The reported sensitivities and associated uncertainties will be used for the calculation of the key comparison reference value.

2 Pilot Laboratory

Pilot laboratory for this regional key comparison is

Vibration and Shock Section
Mechanics and Acoustics Metrology Division
National Institute of Metrology, P.R. China
BeiSanHuanDongLu 18, ChaoYang District, 100013 Beijing, P.R. China

This is the delivery address for the set of artefacts and the written and signed reports.

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Co-Pilot laboratory for this regional key comparison is

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3 Device under Test and Measurement Conditions

For the calibration task of this comparison two quartz-flexure accelerometer sets will be circulated between the participating laboratories. The accelerometer sets are a ‘single ended’ (SE) type, namely a SA 704 (SN: 1022) and a SA 704 (SN: 1022), with one common signal conditioner MSA-I (SN: 02011001).

The accelerometer sets are to be calibrated of their complex voltage sensitivity according to those procedures and conditions implemented by the laboratory in conformance with ISO 16063-11 which provides magnitude information of the artefact. The sensitivities reported shall be for the accelerometer sets, including all effects from the signal conditioner.

The frequency range of the measurements was agreed to be from 0.5 Hz to 20 Hz. Specifically the laboratories are supposed to measure at the following frequencies (all values in Hz).

0.5, 0.63, 0.8, 1, 1.25, 1.6, 2, 2.5, 3.15, 4, 5, 6.3, 8, 10, 12.5, 16, 20.

The measurement conditions should be kept according to the laboratory's standard conditions for calibration of customers’ accelerometers for claiming their best measurement capability or CMC where applicable. This presumes that these conditions comply with those defined by the applicable ISO documentary standards [1,2,3], simultaneously.

Specific conditions for the measurements of this comparison are:

- acceleration amplitudes: a range of 0.1 m/s^2 to 10 m/s^2 is admissible.
- ambient temperature and accelerometer temperature during the calibration:
  (23 ± 2) ºC (actual values to be stated within tolerances of ± 0.3 ºC).
- relative humidity: max. 75 % RH

4 Circulation Type, Schedule and Transportation

The transducer sets are circulated in a star type fashion with a measurement period of two weeks provided for each participating laboratory and one week for the pilot laboratory. At the beginning and the end of the circulation as well as between certain subsequent measurements of participating laboratories, the transducer sets are measured at the pilot laboratory in order to fix reference values and to monitor the stability of the transducer sets.

The schedule is planned as follows:

Participant	Measurement (calendar week)	Transportation to next Participant (calendar week)
NIM	23/2011	24/2011
NMIJ	25-26/2011	27/2011
KRISS	28-29/2011	30/2011
NIM	31/2011	32/2011
NIMT	33-34/2011	35/2011
CMS	36-37/2011	38/2011
NIM	39/2011	40/2011
NMIA	41-42/2011	43/2011
NMISA	44-45/2011	46/2011
NIM	47/2011	

The cost of transportation to the next participating laboratory shall be covered by the participating laboratory. The transducer sets have to be sent hand-carried with great caution. In case the transducer sets get damaged or lost during transportation, the participating laboratory for delivery should pay 4 000,- € to pilot laboratory for each set.

5 Measurement and Analysis Instructions

The participating laboratories have to observe the following instructions:

- The motion of the quartz-flexure accelerometer should be measured on the moving part of the vertical (preferably) or horizontal vibration exciter, close to the accelerometer's mounting surface, since the mounting (reference) surface is usually not directly accessible.

- The mounting surface of the accelerometer and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and signal conditioner should be taken from the set delivered to the laboratory.
- In order to reduce the influence of non-rectilinear motion, the measurements should be performed for at least three different laser positions which are symmetrically distributed over the respective measurement surface.
- It is advised that the measurement results should be compiled from complete measurement series carried out at different days under nominally the same conditions, except that the accelerometer is remounted and the cable re-attached. The standard deviation of the subsequent measurements should be included in the report.

6 Communication of the Results to Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report for each accelerometer set to the pilot laboratory including the following:

- a description of the calibration systems used for the comparison and the mounting techniques for the accelerometer
- a description of the calibration methods used
- documented record of the ambient conditions during measurements
- the calibration results, including the relative expanded measurement uncertainty, and the applied coverage factor for each value
- a detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to GUM [4,5]). Including, among others, information on the type of uncertainty (A or B), assumed distribution function and repeatability component.

In addition, the use of the electronic spreadsheets for reporting is mandatory. The consistency between the results in electronic form and the printed and signed calibration report is the responsibility of the participating laboratory. The data submitted in the electronic spreadsheet shall be deemed the official results submitted for the comparison.

The results have to be submitted to the pilot laboratory within six weeks after the measurements have been completed.

The pilot laboratory will submit its set of results to the executive secretary of CCAUV in advance to the first measurement of the participating laboratory.

7 Remarks on post processing

Presuming consistency of the results, the comparison reference value will be calculated according to the established methods agreed upon already for CCAUV.V-K1. The results of this APMP comparison will serve as the foundation of the registration of ‘calibration and measurement capabilities’ (CMC) for low-frequency vibration by the participating NMIs in the framework of the CIPM MRA.

References

[1] ISO 16063-1:1998 ‘Methods for the calibration of vibration and shock transducers -- Part 1: Basic concepts

[2] ISO 16063-11:1999 ‘Methods for the calibration of vibration and shock transducers-- Part 11: Primary vibration calibration by laser interferometry’

[3] ISO/IEC 17025:2005 ‘General requirements for the competence of testing and calibration laboratories’

[4] ISO/IEC Guide 98-3:2008 ‘Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

[5] ISO/IEC Guide 98-3:2008/Suppl 1:2008 ‘Propagation of distributions using a Monte Carlo method’

Appendix B: Uncertainty Budgets of the participants

NIM (self-developed shakers):

UNCERTAINTY BUDGET MATRIX (UBM)

Certificate No	#REF!
Procedure No	AUVV-0001

Reference: Guide to the Expression of Uncertainty in Measurement, issued by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML - ISO 1995 (ISBN 92-67-10188-9)

Description	Sensitivty calibration (modulus) as per ISO 16063-11 method 3	Make & model:	China SA-704	Range:	0.1Hz to 20 Hz	Metrologist
		Serial number:	1021/1022			YANG Lifeng

Mathematical Model: $S=\hat{u}/\hat{a}=\hat{u}/(2\pi f)^2 d$

Symbol	Input Quantity (Source of Uncertainty)	Estimated Uncertainty		Probability Distribution	*k*	Divisor factor	Standard Uncertainty	Sensitivity Coefficient		Standard Uncertainty Contribution *Ui*(y)	Reliability	Degrees of Freedom	Remarks
u	▼ Standards and Reference Equipment (Uncorrelated) ▼	(Xi)	Unit	(N, R, T, U)	▼	▼	U(Xi)	Ci	Unit	%	%	*v*	
φ_Q	Interferometer output signal disturbance on phase amplitude	0.01	%	Rectangular √3	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	e.g. offsets, voltage amplitude deviations, <> 90° Corrected with Heydemann procedure
φ_{VD}	Effect of voltage disturbance on phase amplitude measurement	0.01	%	Rectangular √3	2.00	1.73	5.77E-03	0.01	%	0.000	100	infinite	Additive uncorrelated noise is reduced by 1/√n. Where n=number of samples per vibration cycle. Worse case
φ_{MD}	Effect of motion disturbance on phase amplitude measurement	0.01	%	Rectangular √3	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	Relative motion between sensing spot, exiter and accelerometer.
φ_{PD}	Effect of phase disturbance on phase amplitude measurement	0.01	%	Rectangular √3	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	Corrected for using Heydemann correction procedure
φ_{RE}	Residual interferometric effects on phase amplitude measurement	0.02	%	Rectangular √3	2.00	1.73	1.15E-02	1	%	0.012	100	infinite	Not aware of any
f_{FG}	Vibration frequency measurement accuracy	0.0002	%	Rectangular √3	2.00	1.73	1.15E-04	1	%	0.000	100	infinite	ISO 16063-11 requirement: ≤0,05 % of reading
λ_U	Uncertainty on laser wavelength measurement	2.50E-11	nm	Normal k = 2	2.00	2.00	1.25E-11	100	%	0.000	100	infinite	Uncertainty quoted on certificate
$\hat{u}_V$	Accelerometer output voltage measurement (ADC resolution/accuracy)	0.1	%	Rectangular √3	2.00	1.73	5.77E-02	1	%	0.058	100	infinite	Manufacturer's specification worse case on 1 V range
S_F	Filtering effect on sensitivity measurement	0	%	Rectangular √3	2.00	1.73	0.00E+00	1	%	0.000	100	infinite	$e=(f/f_{Hp})^2$
G_{CA}	Charge amplifier gain accuracy	0.00	%	Normal k = 2	2.00	2.00	0.00E+00	1	%	0.000	100	infinite	Conditiong amplifier uncertainty
	Resolution of Standard / Equipment (If applicable)										100		
	▼ Unit Under Test / Calibration (Uncorrelated) ▼				NOTE! *ONLY CHANGE BLUE CELLS - All OTHER CELLS (WHITE) ARE PROTECTED*								
$\hat{u}_D$	Effect of voltage disturbance on accelerometer output voltage	0.001	%	Rectangular √3		1.73	5.774E-04	1	%	0.001	100	infinite	U_{THD} = ½(d/100)²; Maximum allowed by ISO
$\hat{u}_T$	Effect of transverse motion on accelerometer output voltage measurement	0.06	%	Rectangular √3		1.73	3.464E-02	1	%	0.035	100	infinite	Transeverse error for a transverse sensitivity of 1%
$\hat{u}_{RES}$	Residual effects on accelerometer output voltage measurement	0.1	%	Normal k = 3		3.00	3.333E-02	1	%	0.033	100	infinite	Tribo-electric effect
$\hat{u}_\sigma$	Standard deviation on accelerometer output voltage measurement	0.16	%	Normal k = 3		3.00	5.333E-02	1	%	0.053	100	infinite	ESDM for sensitivity calulation using 5 cycles min
	Resolution of UUT / Equipment (If applicable)										100		
	Data - Type "B" Evaluation Range of the results (Rectangular)										100		
	Data - Type "A" Evaluation Exp Std Dev of the Mean (ESDM)			Normal *k* = 1								4	No of Readings 5
About UBM	TOTAL COMBINED UNCERTAINTY									%			

Best Measurement Capability (Excluding UUT contribution)	Combined Uncertainty (Normal)	▼ Level of Confidence ▼	0.060	V_{eff}	infinite	Checked and Approved By:
	Expanded Uncertainty	95,45 % k = 2	0.120	*k* =	2.00	
Uncertainty of Measurement (Including UUT contribution)	Combined Uncertainty (Normal)	▼ Level of Confidence ▼	0.093	V_{eff}	infinite	SUN Qiao
	Expanded Uncertainty	95,45 % k = 2	0.2	*k* =	2.00	

NIMT (APS 113 shaker):

Uncertainty of Magnitude for Accelerometer SA-704 s/n1021

Frequency (Hz)	0.5	0.63	0.8	1	1.25	1.6	2	2.5	3.15	4	5	6.3	8	10	12.5	16	20
U1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
U2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
U3	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
U4	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	0.02	0.02	0.02
U5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05
U6	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
U7	0.001	0.001	0.001	0.00	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
U8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
U9	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
U10	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
U11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U12	0.25	0.25	0.25	0.2	0.2	0.2	0.18	0.18	0.18	0.18	0.16	0.16	0.16	0.14	0.14	0.14	0.14
U13	0.05	0.05	0.05	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.001	0.001	0.001
U14	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
U15	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
U16	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
U17	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
U18	0.0018	0.0038	0.0028	0.0018	0.0000	0.0017	0.0013	0.0017	0.0027	0.0000	0.0018	0.0000	0.0013	0.0013	0.0028	0.0032	0.0040
Uc	**0.298**	**0.298**	**0.298**	**0.254**	**0.254**	**0.254**	**0.238**	**0.238**	**0.238**	**0.238**	**0.205**	**0.205**	**0.205**	**0.190**	**0.190**	**0.190**	**0.190**
Ue	**0.597**	**0.597**	**0.597**	**0.507**	**0.507**	**0.507**	**0.475**	**0.475**	**0.475**	**0.475**	**0.411**	**0.411**	**0.411**	**0.380**	**0.380**	**0.380**	**0.380**

Uncertainty of Magnitude for Accelerometer SA-704 s/n1022

Frequency	0.5	0.63	0.8	1	1.25	1.6	2	2.5	3.15	4	5	6.3	8	10	12.5	16	20
U1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
U2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
U3	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
U4	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	0.02	0.02	0.02
U5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05
U6	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
U7	0.001	0.001	0.001	0.00	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
U8	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
U9	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
U10	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
U11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U12	0.25	0.25	0.25	0.2	0.2	0.2	0.18	0.18	0.18	0.18	0.16	0.16	0.16	0.14	0.14	0.14	0.14
U13	0.05	0.05	0.05	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.001	0.001	0.001
U14	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
U15	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
U16	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
U17	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
U18	0.0017	0.0038	0.0013	0.0017	0.0018	0.0013	0.0017	0.0013	0.0013	0.0018	0.0000	0.0017	0.0000	0.0013	0.0000	0.0000	0.0018
Uc	**0.298**	**0.298**	**0.298**	**0.254**	**0.254**	**0.254**	**0.238**	**0.238**	**0.238**	**0.238**	**0.205**	**0.205**	**0.205**	**0.190**	**0.190**	**0.190**	**0.190**
Ue	**0.597**	**0.597**	**0.597**	**0.507**	**0.507**	**0.507**	**0.475**	**0.475**	**0.475**	**0.475**	**0.411**	**0.411**	**0.411**	**0.380**	**0.380**	**0.380**	**0.380**

DETAIL OF UNCERTAINTY BUDGET FOR MAGNITUDE CALIBRATION

Type	Source of Uncertainty	Symbol	Probability Distribution	Divisor	Ci	u(xi)	Υ_{eff}
B	Vibration velocity (uncertainty of tracing back)	U_1	normal	2	1	$\frac{U_1}{2}$	∞
B	Voltage U_x	U_2	normal	2	1	$\frac{U_2}{2}$	∞
B	Angular frequency of v signal	U_3	square	$\sqrt{3}$	1	$\frac{U_3}{\sqrt{3}}$	∞
B	Amplifier gain	U_4	normal	2	1	$\frac{U_4}{2}$	∞
B	Frequency response	U_5	normal	2	1	$\frac{U_5}{2}$	∞
B	Transverse motion	U_6	square	$\sqrt{3}$	1	$\frac{U_6}{\sqrt{3}}$	∞
B	Harmonics	U_7	square	$\sqrt{3}$	1	$\frac{U_7}{\sqrt{3}}$	∞
B	Hum	U_8	normal	2	1	$\frac{U_8}{2}$	∞
B	Noise	U_9	normal	2	1	$\frac{U_9}{2}$	∞
B	Effect of geometric location	U_{10}	square	$\sqrt{3}$	1	$\frac{U_{10}}{\sqrt{3}}$	∞
B	Sensor attachment	U_{11}	square	$\sqrt{3}$	1	$\frac{U_{11}}{\sqrt{3}}$	∞
B	Cable routing and fixing	U_{12}	square	$\sqrt{3}$	1	$\frac{U_{12}}{\sqrt{3}}$	∞
B	Relative motion	U_{13}	square	$\sqrt{3}$	1	$\frac{U_{13}}{\sqrt{3}}$	∞
B	Temperature change	U_{14}	square	$\sqrt{3}$	1	$\frac{U_{14}}{\sqrt{3}}$	∞

B	Linearity	U_{15}	square	$\sqrt{3}$	1	$\frac{U_{15}}{\sqrt{3}}$	∞
B	Temporal instability of v signal	U_{16}	square	$\sqrt{3}$	1	$\frac{U_{16}}{\sqrt{3}}$	∞
B	Residual effects	U_{17}	square	$\sqrt{3}$	1	$\frac{U_{17}}{\sqrt{3}}$	∞
A	Repeatability	U_{18}	normal	1	1	$\frac{U_{17}}{\sqrt{n}}$	n
	Combined Uncertainty	U_c	normal				
	Expanded Uncertainty	U_e	normal $(k=2)$				
	Approved Uncertainty	U					

CMS (APS 113 shaker):

Uncertainty for 1021

Description	0.5	0.63	0.8	1	1.25	1.6	2	2.5	3.15	4
Uncertainty of accelerometer output voltage measurement (Voltmeter)	0.347314%	0.553592%	0.230044%	0.234321%	0.250953%	0.219515%	0.194243%	0.057703%	0.002667%	0.059548%
Quantization effect of RMS volt meter	0.800000%	0.800000%	0.750000%	0.750000%	0.750000%	0.750000%	0.750000%	0.750000%	0.020000%	0.020000%
Uncertainty of total distortion on accelerometer output voltage measurement	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.100000%	0.100000%
Uncertainty of transverse, rocking and bending acceleration on accelerometer output voltage	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.120000%	0.120000%
Uncertainty of trigger hysteresis on displacement measurement	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%
Uncertainty of displacement measurement (interferometer signal)	0.227217%	0.227217%	0.140582%	0.067315%	0.064880%	0.084854%	0.104261%	0.058465%	0.050267%	0.126004%
Effect of ratio measurement	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.050000%	0.050000%
Uncertainty of laser wave length	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%
Uncertainty of displacement quantization on displacement measurement	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%
Uncertainty of vibration frequency measurement (frequency generator)	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%
Uncertainty of standard voltage generator	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%
Uncertainty of motion disturbance on displacement measurement (relative motion between the accelerometer reference surface and the spot sensed by the interferometer; thermal effect)	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.100000%	0.100000%
other effects on sensitivity measurement (random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0.210000%	0.210000%	0.205000%	0.205000%	0.205000%	0.205000%	0.205000%	0.205000%	0.025000%	0.025000%
Relative combined uncertainty $u_{rc}(Su)$	1.34E-02	1.35E-02	1.18E-02	1.16E-02	1.15E-02	1.14E-02	1.12E-02	1.11E-02	2.57E-03	2.49E-03
Effective degree of freedom v	420	401	318	300	292	279	268	251	514	556
Coverage factor k	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.96	1.96
Relative expanded uncertainty U_r	2.63%	2.65%	2.32%	2.28%	2.27%	2.24%	2.21%	2.18%	0.50%	0.49%

Uncertainty for 1021

Description	5	6.3	8	10	12.5	16	20	Uncertainty Type
Uncertainty of accelerometer output voltage measurement (Voltmeter)	0.042694%	0.000239%	0.001782%	0.000212%	0.001555%	0.002043%	0.001848%	A
Quantization effect of RMS volt meter	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	B
Uncertainty of total distortion on accelerometer output voltage measurement	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	B
Uncertainty of transverse, rocking and bending acceleration on accelerometer output voltage	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	B
Uncertainty of trigger hysteresis on displacement measurement	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	B
Uncertainty of displacement measurement (interferometer signal)	0.108349%	0.036147%	0.042910%	0.021321%	0.021089%	0.008314%	0.039861%	A
Effect of ratio measurement	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	B
Uncertainty of laser wave length	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	B
Uncertainty of displacement quantization on displacement measurement	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	B
Uncertainty of vibration frequency measurement (frequency generator)	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	B
Uncertainty of standard voltage generator	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	B
Uncertainty of motion disturbance on displacement measurement (relative motion between the accelerometer reference surface and the spot sensed by the interferometer; thermal effect)	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	B
other effects on sensitivity measurement (random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	B
Relative combined uncertainty $u_{rc}(Su)$	2.19E-03	2.13E-03	2.08E-03	2.07E-03	2.05E-03	2.08E-03	2.23E-03	
Effective degree of freedom v	461	418	383	375	364	384	435	
Coverage factor k	1.97	1.97	1.97	1.97	1.97	1.97	1.97	
Relative expanded uncertainty U_r	0.43%	0.42%	0.41%	0.41%	0.40%	0.41%	0.44%	

Uncertainty for 1022

Description	0.5	0.63	0.8	1	1.25	1.6	2	2.5	3.15	4
Uncertainty of accelerometer output voltage measurement (Voltmeter)	0.311779%	0.558033%	0.417666%	0.257401%	0.258720%	0.172287%	0.175017%	0.035893%	0.052102%	0.079553%
Quantization effect of RMS volt meter	0.800000%	0.800000%	0.750000%	0.750000%	0.750000%	0.750000%	0.750000%	0.750000%	0.020000%	0.020000%
Uncertainty of total distortion on accelerometer output voltage measurement	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.600000%	0.100000%	0.100000%
Uncertainty of transverse, rocking and bending acceleration on accelerometer output voltage	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.350000%	0.120000%	0.120000%
Uncertainty of trigger hysteresis on displacement measurement	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%
Uncertainty of displacement measurement (interferometer signal)	0.199727%	0.199727%	0.157201%	0.108067%	0.092004%	0.042317%	0.078550%	0.131520%	0.124935%	0.119971%
Effect of ratio measurement	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.200000%	0.050000%	0.050000%
Uncertainty of laser wave length	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%
Uncertainty of displacement quantization on displacement measurement	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%
Uncertainty of vibration frequency measurement (frequency generator)	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%
Uncertainty of standard voltage generator	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%
Uncertainty of motion disturbance on displacement measurement (relative motion between the accelerometer reference surface and the spot sensed by the interferometer; thermal effect)	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.270000%	0.100000%	0.100000%
other effects on sensitivity measurement (random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0.210000%	0.210000%	0.205000%	0.205000%	0.205000%	0.205000%	0.205000%	0.205000%	0.025000%	0.025000%
Relative combined uncertainty $u_{rc}(Su)$	1.32E-02	1.35E-02	1.23E-02	1.17E-02	1.15E-02	1.13E-02	1.13E-02	1.11E-02	2.59E-03	2.91E-03
Effective degree of freedom ν	408	403	359	306	291	270	271	255	565	396
Coverage factor k	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.96	1.97
Relative expanded uncertainty U_r	2.60%	2.66%	2.42%	2.30%	2.27%	2.22%	2.22%	2.19%	0.51%	0.57%

Uncertainty for 1022								
Description	5	6.3	8	10	12.5	16	20	Uncertainty Type
Uncertainty of accelerometer output voltage measurement (Voltmeter)	0.058676%	0.001567%	0.000881%	0.000796%	0.001223%	0.000244%	0.001666%	A
Quantization effect of RMS volt meter	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	0.020000%	B
Uncertainty of total distortion on accelerometer output voltage measurement	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	B
Uncertainty of transverse, rocking and bending acceleration on accelerometer output voltage	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	0.120000%	B
Uncertainty of trigger hysteresis on displacement measurement	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	0.030000%	B
Uncertainty of displacement measurement (interferometer signal)	0.177374%	0.060510%	0.051937%	0.048200%	0.080178%	0.071004%	0.083732%	A
Effect of ratio measurement	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	B
Uncertainty of laser wave length	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	0.002000%	B
Uncertainty of displacement quantization on displacement measurement	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	0.010200%	B
Uncertainty of vibration frequency measurement (frequency generator)	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	0.010000%	B
Uncertainty of standard voltage generator	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	0.050000%	B
Uncertainty of motion disturbance on displacement measurement (relative motion between the accelerometer reference surface and the spot sensed by the interferometer; thermal effect)	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	0.100000%	B
other effects on sensitivity measurement (random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	0.025000%	B
Relative combined uncertainty $u_{rc}(Su)$	2.28E-03	2.15E-03	2.13E-03	2.21E-03	2.17E-03	2.21E-03	2.07E-03	
Effective degree of freedom v	514	430	411	440	426	434	374	
Coverage factor k	1.96	1.97	1.97	1.97	1.97	1.97	1.97	
Relative expanded uncertainty U_r	0.45%	0.42%	0.42%	0.43%	0.43%	0.43%	0.41%	

NMIA (APS 113 shaker):

Primary vibration calibration by laser interferometry (ISO 16063-11:1999, Method 1, Fringe Counting). NMIA						
Source of uncertainty	**Symbol**	**Distribution**	**Factor**	**Sensitivity coefficient**	**Degrees of freedom**	**%**
Accelerometer output voltage measurement (voltmeter)	u1	normal	1	1	30	**0.0500**
Effect of total distortion on accelerometer output voltage measurement	u2	rectangular	0.58	1	10	**0.0100**
Effect of spurious sensitivities on accelerometer output voltage measurement	u3	rectangular	0.58	1	10	**0.0208**
Effect of displacement quantization on displacement measurement	u4	rectangular	0.58	1	30	**0.0015**
Effect of trigger hysteresis of fringe counter on displacement measurement	u5	rectangular	0.58	1	10	**0.0012**
Filtering effect on displacement measurement (freq band limitation)	u6	rectangular	0.58	1	30	**0.0000**
Effect of voltage disturbance on displacement measurement (e.g. random noise in photoelectric measuring chain)	u7	rectangular	0.58	1	30	**0.0058**
Effect of motion disturbance on displacement measurements (e.g. total distortion, relative motion between accelerometer ref surface and spot sensed by interferometer)	u8	rectangular	0.58	1	10	**0.0064**
Effect of phase disturbance of displacement measurement (e.g. phase noise of interferometer signal)	u9	rectangular	0.58	1	30	**0.0000**
function)	u10	rectangular	0.58	1	30	**0.0022**
Vibration frequency measurement (frequency generator and indicator counter)	u11	rectangular	0.58	1	30	**0.0006**
measurements, ESDM, including any effects of the signal conditioning instrument	u12	normal	1	1	26	**0.0600**
Effect of motion exciter mode	u13	rectangular	0.58	1	10	**0.0462**
Rounding error	u14	rectangular	0.58	1	100	**0.0023**

Primary vibration calibration by laser interferometry (ISO 16063-11:1999, Method 3, Sine Approximation), NMIA						
Source of uncertainty	**Symbol**	**Distribution**	**Factor**	**Sensitivity coefficient**	**Degrees of freedom**	**%**
Accelerometer output voltage measurement (voltmeter)	u1	normal	1	1	30	**0.0500**
Voltage filtering effect on accelerometer output voltage measurement	u2	rectangular	0.58	1	10	**0.0000**
Effect of voltage disturbance on accelerometer output voltage measurement	u3	rectangular	0.58	1	10	**0.0000**
Effect of transverse, rocking and bending acceleration on accelerometer output voltage measurement	u4	rectangular	0.58	1	30	**0.0208**
Effect of interferometer quadrature output signal disturbance on phase amplitude measurement	u5	rectangular	1	1	10	**0.0300**
Interferometer signal filtering effect on phase amplitude measurement	u6	rectangular	0.58	1	30	**0.0000**
Effect of voltage disturbance phase amplitude measurement	u7	rectangular	0.58	1	30	**0.0058**
Effect of motion disturbance on phase amplitude measurements (e.g. total distortion, relative motion between accelerometer ref surface and spot sensed by interferometer)	u8	rectangular	0.58	1	10	**0.0064**
Effect of phase disturbance of phase amplitude measurement (e.g. phase noise of interferometer signal)	u9	rectangular	0.58	1	30	**0.0000**
function)	u10	rectangular	0.58	1	30	**0.0022**
Vibration frequency measurement (frequency generator and indicator counter)	u11	rectangular	0.58	1	30	**0.0006**
measurements, ESDM, including any effects of the signal conditioning instrument	u12	normal	1	1	26	**0.0300**
Effect of motion exciter mode	u13	rectangular	0.58	1	10	**0.0115**
Rounding error	u14	rectangular	0.58	1	100	**0.0023**

Component	**Uncertainty**	**Degrees of freedom**
Quadrature sum of all correlated sources, Fringe Counting	0.05579%	42
Quadrature sum of all correlated sources, Sine Approximation	0.05489%	42
Quadrature sum of all uncorrelated sources, Fringe Counting	0.07578%	35
Quadrature sum of all uncorrelated sources, Sine Approximation	0.04403%	33
uc2	0.006903%^2	
uc	0.08309%	32
k uc (k=2)	0.17%	
U95, rounded up	**0.2%**	

NMISA (APS 113 shaker):

UNCERTAINTY BUDGET MATRIX (UBM)		Certificate No	AVVS-2778
		Procedure No	AVVS-0001

Reference: Guide to the Expression of Uncertainty in Measurement, issued by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML - ISO 1995 (ISBN 92-67-10188-9)

escription	Sensitivty calibration (modulus) as per ISO 16063-11 method 3	Make & model:	China SA-704	Range:	0,4 Hz to 50 Hz	Metrologist
		Serial number:	1021/1022			Ian Veldman

Mathematical Model: $S=\hat{u}/\hat{a}=\hat{u}/(2\pi f)^2 d$

Symbol	Input Quantity (Source of Uncertainty)	Estimated Uncertainty		Probability Distribution	k	Divisor factor	Standard Uncertainty	Sensitivity Coefficient		Standard Uncertainty Contribution Ui(y)	Reliability	Degrees of Freedom	Remarks
u	▼ Standards and Reference Equipment (Uncorrelated) ▼	(Xi)	Unit	(N, R, T, U)	▼	▼	U(Xi)	Ci	Unit	%	%	v	
φ_Q	Interferometer output signal disturbance on phase amplitude	0.01	%	Rectangular	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	e.g. offsets, voltage amplitude deviations, <> 90° Corrected with Heydemant procedure
φ_{VD}	Effect of voltage disturbance on phase amplitude measurement	0.01	%	Rectangular	2.00	1.73	5.77E-03	0.01	%	0.000	100	infinite	Additive uncorrelated noise is reduced by 1/√n. Where n=number of samples per vibration cycle. Worse case
φ_{MD}	Effect of motion disturbance on phase amplitude measurement	0.015	%	Rectangular	2.00	1.73	8.66E-03	1	%	0.009	100	infinite	Relative motion between sensing spot, exiter and accelerometer.
φ_{PD}	Effect of phase disturbance on phase amplitude measurement	0.01	%	Rectangular	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	Corrected for using Heydemann correction procedure
φ_{RE}	Residual interferometric effects on phase amplitude measurement	0.01	%	Rectangular	2.00	1.73	5.77E-03	1	%	0.006	100	infinite	Not aware of any
f_{FG}	Vibration frequency measurement accuracy	0.05	%	Rectangular	2.00	1.73	2.89E-02	1	%	0.029	100	infinite	ISO 16063-11 requirement: ≤ 0,05 % of reading
λ_U	Uncertainty on laser wavelength measurement	2.50E-11	nm	Normal k = 2	2.00	2.00	1.25E-11	100	%	0.000	100	infinite	Uncertainty quoted on certificate
$\hat{u}_V$	Accelerometer output voltage measurement (ADC resolution/accuracy)	0.15	%	Rectangular	2.00	1.73	8.66E-02	1	%	0.087	100	infinite	Manufacturer's specification worse case on 1 V range
S_F	Filtering effect on sensitivity measurement	0.11	%	Rectangular	2.00	1.73	6.35E-02	1	%	0.064	100	infinite	$e=(f/f_{Hp})^2$
G_{CA}	Conditioning amplifier gain accuracy	0.00	%	Normal k = 2	2.00	2.00	0.00E+00	1	%	0.000	100	infinite	N/A Calibrated as a unit
	Resolution of Standard / Equipment (If applicable)										100		
	▼ Unit Under Test / Calibration (Uncorrelated) ▼				NOTE! *ONLY CHANGE BLUE CELLS - All OTHER CELLS (WHITE) ARE PROTECTED*								
$\hat{u}_D$	Effect of voltage disturbance on accelerometer output voltage	0.005	%	Rectangular		1.73	2.887E-03	1	%	0.003	100	infinite	U_{THD} = ½(d/100)²; Maximum allowed by ISO
$\hat{u}_T$	Effect of transverse motion on accelerometer output voltage measurement	0.1	%	Rectangular		1.73	5.774E-02	1	%	0.058	100	infinite	Transeverse error for a transverse sensitivity of 1%
$\hat{u}_{RES}$	Residual effects on accelerometer output voltage measurement	0.1	%	Normal k = 2		2.00	5.000E-02	1	%	0.050	100	infinite	Tribo-electric effect
$\hat{u}_\sigma$	Standard deviation on accelerometer output voltage measurement	0.2	%	Normal k = 2		2.00	1.000E-01	1	%	0.100	100	infinite	ESDM for sensitivity calulation using 5 cycles min
	Resolution of UUT / Equipment (If applicable)										100		
	Data - Type "B" Evaluation Range of the results (Rectangular)										100		
	Data - Type "A" Evaluation Exp Std Dev of the Mean (ESDM)			Normal k = 1								4	No of Readings 5
About UBM	TOTAL COMBINED UNCERTAINTY									%			

Best Measurement Capability (<u>Excluding</u> UUT contribution)	Combined Uncertainty (Normal)	▼ Level of Confidence ▼	0.112	V_{eff}	infinite	Checked and Approved By:
	Expanded Uncertainty	95,45 % k = 2	0.224	k =	2.00	
Uncertainty of Measurement (Including UUT contribution)	Combined Uncertainty (Normal)	▼ Level of Confidence ▼	0.168	V_{eff}	infinite	
	Expanded Uncertainty	95,45 % k = 2	0.3	k =	2.00	

NMIJ (self-developed shakers):

DUT	Pickup : SA704 (SN: 1021) Signal Conditioner: MSA-I (SN: 02011001)

Frequency	Calibration system	Method	Acceleration	Sensitivity	Expanded uncertainty (k=2)	Conbined uncertainty	Expanded uncertainty (k=2)	Effect of internal calibration of voltmeter using voltage standard				Voltage standard uncertainty			
Hz			m/s^2	$mV/(m/s^2)$	$mV/(m/s^2)$	%	%	%	Type	Distribution	DOF	%	Type	Distribution	DOF
0.5	Ultra low	FCM	0.5	124.81	2.41	0.97	1.93	1.3E-01	A	Normal	9	5.0E-02	B	Normal	∞
0.63	Ultra low	FCM	1	123.93	0.92	0.37	0.74	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
0.8	Ultra low	FCM	1	123.85	1.03	0.42	0.83	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
1	Ultra low	FCM	1	123.91	1.13	0.46	0.91	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
1.25	Ultra low	FCM	2	123.76	0.83	0.33	0.67	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
1.6	Ultra low	FCM	2	123.79	0.53	0.22	0.43	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
2	Ultra low	FCM	2	123.88	0.79	0.32	0.64	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
2.5	Low	FCM	5	123.86	0.36	0.14	0.29	5.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
3.15	Low	FCM	5	123.91	0.26	0.11	0.21	5.2E-03	A	Normal	9	5.0E-02	B	Normal	∞
4	Low	FCM	5	123.94	0.26	0.10	0.21	5.3E-03	A	Normal	9	5.0E-02	B	Normal	∞
5	Low	FCM	10	123.95	0.40	0.16	0.33	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
6.3	Low	FCM	10	123.98	0.33	0.13	0.27	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
8	Low	FCM	10	124.01	0.30	0.12	0.24	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
10	Low	FCM	10	124.05	0.28	0.11	0.23	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
12.5	Low	FCM	10	124.11	0.28	0.11	0.22	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
16	Low	FCM	10	124.20	0.27	0.11	0.22	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
20	Low	FCM	10	124.34	0.27	0.11	0.22	2.3E-03	A	Normal	9	5.0E-02	B	Normal	∞

Effect of voltage quantization on measurement by voltmeter				Effect of transverse sensitivity on accelerometer output voltage measurement				Effect of total distortion of accelerometer output voltage				Repeatability of sensitivity				Effect of laser wavelength instability			
%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.9E-03	B	Normal	∞	9.5E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.9E-03	B	Normal	∞	3.4E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	9.1E-04	B	Normal	∞	4.0E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.1E-03	B	Normal	∞	4.4E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.2E-02	B	Normal	∞	3.0E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	6.5E-03	B	Normal	∞	1.8E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	5.5E-03	B	Normal	∞	3.0E-01	A	Normal	20	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.5E-02	B	Normal	∞	1.4E-02	B	Normal	∞	1.5E-02	A	Normal	29	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.4E-02	B	Normal	∞	5.0E-03	B	Normal	∞	6.8E-03	A	Normal	29	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.3E-02	B	Normal	∞	2.6E-03	B	Normal	∞	1.2E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.2E-02	B	Normal	∞	6.6E-03	B	Normal	∞	1.1E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.1E-02	B	Normal	∞	3.3E-03	B	Normal	∞	5.0E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.0E-02	B	Normal	∞	1.8E-03	B	Normal	∞	6.4E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	9.0E-03	B	Normal	∞	1.2E-03	B	Normal	∞	5.1E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	9.0E-03	B	Normal	∞	9.8E-04	B	Normal	∞	4.4E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.1E-02	B	Normal	∞	6.5E-04	B	Normal	∞	3.6E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.0E-02	B	Normal	∞	5.6E-04	B	Normal	∞	1.7E-02	A	Normal	29	1.6E-03	B	Normal	∞

Effect of vibration frequency instability				Effect of displacement quantization on displacement measurement by universal counter				Effect of displacement quantization on measurement by laser interferometer				Effect of displacement distortion on displacement measurement				Effect of remounting accelerometer			
%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF
5.3E-02	B	Normal	∞	6.4E-05	B	Triangular	∞	6.4E-05	B	Triangular	∞	4.2E-02	B	Normal	∞	5.8E-02	B	Normal	∞
5.7E-02	B	Normal	∞	5.1E-05	B	Triangular	∞	5.1E-05	B	Triangular	∞	4.6E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.7E-02	B	Normal	∞	8.2E-05	B	Triangular	∞	8.2E-05	B	Triangular	∞	2.7E-02	B	Normal	∞	5.8E-02	B	Normal	∞
1.2E-02	B	Normal	∞	1.3E-04	B	Triangular	∞	1.3E-04	B	Triangular	∞	2.3E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.1E-03	B	Normal	∞	1.0E-04	B	Triangular	∞	1.0E-04	B	Triangular	∞	1.2E-01	B	Normal	∞	5.8E-02	B	Normal	∞
1.6E-03	B	Normal	∞	1.6E-04	B	Triangular	∞	1.6E-04	B	Triangular	∞	9.1E-02	B	Normal	∞	5.8E-02	B	Normal	∞
2.6E-03	B	Normal	∞	2.5E-04	B	Triangular	∞	2.5E-04	B	Triangular	∞	8.4E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.9E-03	B	Normal	∞	1.6E-04	B	Triangular	∞	1.6E-04	B	Triangular	∞	1.0E-01	B	Normal	∞	8.6E-02	B	Normal	∞
4.4E-03	B	Normal	∞	2.5E-04	B	Triangular	∞	2.5E-04	B	Triangular	∞	3.2E-02	B	Normal	∞	8.6E-02	B	Normal	∞
3.9E-03	B	Normal	∞	4.1E-04	B	Triangular	∞	4.1E-04	B	Triangular	∞	2.2E-02	B	Normal	∞	8.6E-02	B	Normal	∞
5.6E-03	B	Normal	∞	3.2E-04	B	Triangular	∞	3.2E-04	B	Triangular	∞	1.3E-01	B	Normal	∞	8.6E-02	B	Normal	∞
5.3E-03	B	Normal	∞	5.1E-04	B	Triangular	∞	5.1E-04	B	Triangular	∞	9.0E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.4E-03	B	Normal	∞	8.2E-04	B	Triangular	∞	8.2E-04	B	Triangular	∞	6.7E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.9E-03	B	Normal	∞	1.3E-03	B	Triangular	∞	1.3E-03	B	Triangular	∞	5.4E-02	B	Normal	∞	8.6E-02	B	Normal	∞
3.7E-04	B	Normal	∞	2.0E-03	B	Triangular	∞	2.0E-03	B	Triangular	∞	4.9E-02	B	Normal	∞	8.6E-02	B	Normal	∞
6.2E-04	B	Normal	∞	3.3E-03	B	Triangular	∞	3.3E-03	B	Triangular	∞	4.0E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.7E-04	B	Normal	∞	5.1E-03	B	Triangular	∞	5.1E-03	B	Triangular	∞	3.7E-02	B	Normal	∞	8.6E-02	B	Normal	∞

DUT	Pickup : SA704 (SN: 1022) Signal Conditioner: MSA-I (SN: 02011001)

Frequency	Calibration system	Method	Acceleration	Sensitivity	Expanded uncertainty (k=2)	Conbined uncertainty	Expanded uncertainty (k=2)	Effect of internal calibration of voltmeter using voltage standard				Voltage standard uncertainty			
Hz			m/s^2	$mV/(m/s^2)$	$mV/(m/s^2)$	%	%	%	Type	Distribution	DOF	%	Type	Distribution	DOF
0.5	Ultra low	FCM	0.5	124.02	2.19	0.88	1.77	1.3E-01	A	Normal	9	5.0E-02	B	Normal	∞
0.63	Ultra low	FCM	1	123.63	0.81	0.33	0.66	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
0.8	Ultra low	FCM	1	123.81	0.92	0.37	0.74	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
1	Ultra low	FCM	1	123.73	1.34	0.54	1.08	8.6E-02	A	Normal	9	5.0E-02	B	Normal	∞
1.25	Ultra low	FCM	2	123.67	0.87	0.35	0.70	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
1.6	Ultra low	FCM	2	123.68	0.47	0.19	0.38	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
2	Ultra low	FCM	2	123.56	0.84	0.34	0.68	2.8E-02	A	Normal	9	5.0E-02	B	Normal	∞
2.5	Low	FCM	5	123.71	0.35	0.14	0.29	5.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
3.15	Low	FCM	5	123.77	0.26	0.11	0.21	5.2E-03	A	Normal	9	5.0E-02	B	Normal	∞
4	Low	FCM	5	123.80	0.26	0.10	0.21	5.3E-03	A	Normal	9	5.0E-02	B	Normal	∞
5	Low	FCM	10	123.82	0.40	0.16	0.33	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
6.3	Low	FCM	10	123.85	0.33	0.13	0.27	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
8	Low	FCM	10	123.88	0.30	0.12	0.24	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
10	Low	FCM	10	123.91	0.28	0.11	0.23	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
12.5	Low	FCM	10	123.97	0.28	0.11	0.22	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
16	Low	FCM	10	124.05	0.27	0.11	0.22	2.1E-03	A	Normal	9	5.0E-02	B	Normal	∞
20	Low	FCM	10	124.17	0.27	0.11	0.21	2.3E-03	A	Normal	9	5.0E-02	B	Normal	∞

Effect of voltage quantization on measurement by voltmeter				Effect of transverse sensitivity on accelerometer output voltage measurement				Effect of total distortion of accelerometer output voltage				Repeatability of sensitivity				Effect of laser wavelength instability			
%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.9E-03	B	Normal	∞	8.7E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.9E-03	B	Normal	∞	3.0E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	9.1E-04	B	Normal	∞	3.5E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-05	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.1E-03	B	Normal	∞	5.3E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	1.2E-02	B	Normal	∞	3.2E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	6.5E-03	B	Normal	∞	1.4E-01	A	Normal	20	1.6E-03	B	Normal	∞
2.9E-04	B	Rectangular	∞	4.0E-03	B	Normal	∞	5.5E-03	B	Normal	∞	3.2E-01	A	Normal	20	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.5E-02	B	Normal	∞	1.4E-02	B	Normal	∞	1.1E-02	A	Normal	29	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.4E-02	B	Normal	∞	5.0E-03	B	Normal	∞	1.2E-02	A	Normal	29	1.6E-03	B	Normal	∞
8.2E-05	B	Rectangular	∞	1.3E-02	B	Normal	∞	2.6E-03	B	Normal	∞	1.3E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.2E-02	B	Normal	∞	6.6E-03	B	Normal	∞	1.1E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.1E-02	B	Normal	∞	3.3E-03	B	Normal	∞	1.2E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.0E-02	B	Normal	∞	1.8E-03	B	Normal	∞	1.5E-02	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	9.0E-03	B	Normal	∞	1.2E-03	B	Normal	∞	6.6E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	9.0E-03	B	Normal	∞	9.8E-04	B	Normal	∞	3.6E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.1E-02	B	Normal	∞	6.5E-04	B	Normal	∞	4.3E-03	A	Normal	29	1.6E-03	B	Normal	∞
4.1E-05	B	Rectangular	∞	1.0E-02	B	Normal	∞	5.6E-04	B	Normal	∞	1.3E-02	A	Normal	29	1.6E-03	B	Normal	∞

Effect of vibration frequency instability				Effect of displacement quantization on displacement measurement by universal counter				Effect of displacement quantization on measurement by laser interferometer				Effect of displacement distortion on displacement measurement				Effect of remounting accelerometer			
%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF	%	Type	Distribution	DOF
5.3E-02	B	Normal	∞	6.4E-05	B	Triangular	∞	6.4E-05	B	Triangular	∞	4.2E-02	B	Normal	∞	5.8E-02	B	Normal	∞
5.7E-02	B	Normal	∞	5.1E-05	B	Triangular	∞	5.1E-05	B	Triangular	∞	4.6E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.7E-02	B	Normal	∞	8.2E-05	B	Triangular	∞	8.2E-05	B	Triangular	∞	2.7E-02	B	Normal	∞	5.8E-02	B	Normal	∞
1.2E-02	B	Normal	∞	1.3E-04	B	Triangular	∞	1.3E-04	B	Triangular	∞	2.3E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.1E-03	B	Normal	∞	1.0E-04	B	Triangular	∞	1.0E-04	B	Triangular	∞	1.2E-01	B	Normal	∞	5.8E-02	B	Normal	∞
1.6E-03	B	Normal	∞	1.6E-04	B	Triangular	∞	1.6E-04	B	Triangular	∞	9.1E-02	B	Normal	∞	5.8E-02	B	Normal	∞
2.6E-03	B	Normal	∞	2.5E-04	B	Triangular	∞	2.5E-04	B	Triangular	∞	8.4E-02	B	Normal	∞	5.8E-02	B	Normal	∞
3.9E-03	B	Normal	∞	1.6E-04	B	Triangular	∞	1.6E-04	B	Triangular	∞	1.0E-01	B	Normal	∞	8.6E-02	B	Normal	∞
4.4E-03	B	Normal	∞	2.5E-04	B	Triangular	∞	2.5E-04	B	Triangular	∞	3.2E-02	B	Normal	∞	8.6E-02	B	Normal	∞
3.9E-03	B	Normal	∞	4.1E-04	B	Triangular	∞	4.1E-04	B	Triangular	∞	2.2E-02	B	Normal	∞	8.6E-02	B	Normal	∞
5.6E-03	B	Normal	∞	3.2E-04	B	Triangular	∞	3.2E-04	B	Triangular	∞	1.3E-01	B	Normal	∞	8.6E-02	B	Normal	∞
5.3E-03	B	Normal	∞	5.1E-04	B	Triangular	∞	5.1E-04	B	Triangular	∞	9.0E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.4E-03	B	Normal	∞	8.2E-04	B	Triangular	∞	8.2E-04	B	Triangular	∞	6.7E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.9E-03	B	Normal	∞	1.3E-03	B	Triangular	∞	1.3E-03	B	Triangular	∞	5.4E-02	B	Normal	∞	8.6E-02	B	Normal	∞
3.7E-04	B	Normal	∞	2.0E-03	B	Triangular	∞	2.0E-03	B	Triangular	∞	4.9E-02	B	Normal	∞	8.6E-02	B	Normal	∞
6.2E-04	B	Normal	∞	3.3E-03	B	Triangular	∞	3.3E-03	B	Triangular	∞	4.0E-02	B	Normal	∞	8.6E-02	B	Normal	∞
4.7E-04	B	Normal	∞	5.1E-03	B	Triangular	∞	5.1E-03	B	Triangular	∞	3.7E-02	B	Normal	∞	8.6E-02	B	Normal	∞

KRISS (APS 129 shaker): Uncertainty budget of the modulus of the voltage sensitivity of standard accelerometer (SA-704 S/N1021).

Freq.	Accel.	Relative standard uncertainty %												$u_c(S)$	$U(S)$
Hz	m/s^2	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	u_{11}	u_{12}	%	% (k=2)
0.5	0.4	0.12	0.06	0.12	0.00	0.00	0.00	0.01	0.12	0.00	0.00	0.00	0.10	0.24	0.47
0.63	0.6	0.09	0.03	0.12	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.09	0.20	0.40
0.8	0.8	0.06	0.02	0.08	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.09	0.14	0.28
1	1.6	0.02	0.01	0.07	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.18	0.21	0.42
1.25	2.0	0.02	0.00	0.06	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.12	0.14	0.28
1.6	2.5	0.01	0.00	0.05	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.19	0.20	0.40
2	6.0	0.03	0.01	0.06	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.08	0.15	0.29
2.5	6.0	0.03	0.00	0.06	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.08	0.13	0.26
3.15	7.1	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.08	0.14	0.27
4	6.1	0.02	0.00	0.05	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.09	0.14	0.28
5	5.4	0.01	0.01	0.05	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.10	0.15	0.29
6.3	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.09	0.14	0.29
8	5.0	0.01	0.01	0.06	0.00	0.00	0.00	0.02	0.10	0.00	0.00	0.00	0.09	0.15	0.30
10	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.00	0.09	0.16	0.31
12.5	5.0	0.01	0.01	0.05	0.01	0.00	0.00	0.03	0.11	0.00	0.00	0.00	0.08	0.15	0.31
16	4.0	0.01	0.01	0.05	0.01	0.00	0.00	0.04	0.09	0.00	0.00	0.00	0.08	0.14	0.29
20	5.0	0.01	0.01	0.05	0.01	0.00	0.00	0.04	0.12	0.00	0.00	0.00	0.06	0.15	0.30

Uncertainty budget of the modulus of the voltage sensitivity of standard accelerometer (SA-704 S/N1022).

Freq.	Accel.	Relative standard uncertainty %												$u_c(S)$	$U(S)$
Hz	m/s^2	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	u_{11}	u_{12}	%	% (k=2)
0.5	0.4	0.12	0.07	0.12	0.00	0.00	0.00	0.01	0.14	0.00	0.00	0.00	0.11	0.25	0.50
0.63	0.6	0.10	0.03	0.12	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.09	0.20	0.40
0.8	0.8	0.06	0.02	0.08	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.08	0.14	0.28
1	1.6	0.02	0.01	0.07	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.11	0.15	0.30
1.25	2.0	0.02	0.00	0.06	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.15	0.17	0.33
1.6	2.5	0.01	0.00	0.05	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.14	0.15	0.30
2	6.0	0.03	0.01	0.06	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.08	0.15	0.30
2.5	6.0	0.03	0.00	0.05	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.08	0.13	0.26
3.15	7.1	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.08	0.14	0.28
4	6.1	0.02	0.00	0.05	0.00	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.09	0.15	0.29
5	5.4	0.01	0.01	0.05	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.10	0.15	0.30
6.3	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.01	0.10	0.00	0.00	0.00	0.09	0.15	0.29
8	5.0	0.01	0.01	0.06	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.00	0.09	0.15	0.31
10	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.00	0.09	0.16	0.31
12.5	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.03	0.12	0.00	0.00	0.00	0.10	0.16	0.33
16	4.0	0.01	0.01	0.05	0.00	0.00	0.00	0.04	0.10	0.00	0.00	0.00	0.10	0.16	0.31
20	5.0	0.01	0.01	0.05	0.00	0.00	0.00	0.04	0.12	0.00	0.00	0.00	0.08	0.16	0.32

Uncertainty components and descriptions for the calibration of standard accelerometers (SA-704).

Symbol	Uncertainty source and description	Type	Distribution function
u_1	Voltage: accelerometer output voltage measurement(voltmeter)	B	rectangular
u_2	Voltage: effect of total distortion and noise on accelerometer output voltage measurement	B	rectangular
u_3	Voltage: transverse motion measurement, etc.	B	rectangular
u_4	Displacement: quantization error of laser interferometer, quantization error of ratio counter	B	triangular
	Displacement: counter calibration	B	normal
u_5	Displacement: trigger hysteresis	B	rectangular
u_6	Displacement: filtering effect	B	rectangular
u_7	Displacement: voltage disturbance	B	rectangular
u_8	Displacement: vibration distortion	B	rectangular
u_9	Displacement: phase disturbance	B	rectangular
u_{10}	Displacement: He-Ne laser stability, misalignment	B	triangular
u_{11}	Frequency: function generator stability	B	rectangular
	Frequency: function generator calibration	B	normal
u_{12}	Sensitivity: repeatability	A	normal
	Sensitivity: deviation of the subsequent measurements, excitation direction etc.	B	rectangular

Appendix C: Degrees of equivalence relative to the KCRV

Results of horizontal voltage sensitivities of the SE-1021:

Frequency→	0.5 Hz		0.63 Hz		0.8 Hz		1 Hz		1.25 Hz		1.6 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**16.9**	19.6	**13.9**	19.7	**12.5**	20.2	**6.3**	19.6	**6.5**	20.2	**6.7**	20.0
CMS	**53.9**	336.3	**87.9**	337.2	**80.5**	299.4	**122.3**	287.8	**94.5**	287.1	**125.7**	287.8
NMIA	**-8.1**	19.5	**-5.1**	19.6	**-4.5**	20.2	**-3.7**	19.6	**-2.5**	20.2	**-2.3**	20.0
NMISA	**-26.1**	33.9	**-22.1**	33.9	**-19.5**	34.3	**-7.7**	33.9	**-5.5**	34.3	**-4.3**	34.2
NMIJ	**64.9**	249.1	**-19.1**	98.0	**-24.5**	98.0	**-16.7**	110.5	**-29.5**	85.4	**-25.3**	60.1
KRISS	**10.9**	60.2	**10.9**	60.2	**3.5**	34.3	**5.3**	60.2	**0.5**	34.3	**2.7**	47.4

Results of horizontal voltage sensitivities of the SE-1021 (continued):

Frequency→	2 Hz		2.5 Hz		3.15 Hz		4 Hz		5 Hz		6.3 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**5.7**	20.2	**5.6**	20.1	**6.7**	20.4	**4.1**	20.4	**6.3**	20.4	**6.0**	20.4
CMS	**62.7**	286.4	**33.6**	273.3	**34.7**	60.6	**71.1**	60.8	**32.3**	60.6	**52.0**	60.7
NMIA	**-5.3**	20.2	**-5.4**	20.1	**-4.3**	20.3	**-7.9**	20.3	**-6.7**	20.3	**-6.0**	20.3
NMISA	**-7.3**	34.3	**-6.4**	34.2	**-15.3**	34.3	**-8.9**	34.4	**-7.7**	34.4	**-8.0**	34.4
NMIJ	**-19.3**	85.5										
KRISS	**8.7**	34.4	**5.6**	34.3	**-2.3**	34.4	**-7.9**	34.4	**-2.7**	34.4	**-11.0**	34.4

Frequency→	8 Hz		10 Hz		12.5 Hz		16 Hz		20 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**6.2**	20.0	**9.5**	20.0	**4.0**	20.2	**7.3**	20.4	**9.7**	20.4
CMS	**50.2**	60.5	**16.5**	60.4	**59.0**	47.8	**72.3**	60.9	**49.7**	60.8
NMIA	**-6.8**	20.0	**-7.5**	20.0	**-10.0**	20.2	**-7.7**	20.4	**-7.3**	20.4
NMISA	**-9.8**	34.2	**-3.5**	34.2	**-11.0**	34.3	**-17.7**	34.4	**-10.3**	34.5
NMIJ										
KRISS	**-11.8**	47.4	**-12.5**	47.4	**-16.0**	47.5	**-7.7**	34.4	**-13.3**	34.5

Results of vertical voltage sensitivities of the SE-1021:

Frequency→	0.5 Hz		0.63 Hz		0.8 Hz		1 Hz		1.25 Hz		1.6 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$	
NIM	**1.1**	7.9	**1.0**	7.9	**0.9**	7.9	**0.6**	9.2	**0.4**	9.2	**0.4**	9.2
NIMT	**-9.9**	70.6	**-9.0**	70.6	**-8.1**	70.6	**-3.4**	57.6	**-2.6**	57.6	**-2.6**	57.6

Frequency→	2 Hz		2.5 Hz		3.15 Hz		4 Hz		5 Hz		6.3 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$	
NIM	**0.6**	9.2	**7.4**	15.3	**6.0**	15.2	**5.1**	15.2	**4.8**	15.9	**3.6**	15.9
NIMT	**-3.4**	57.6	**2.4**	58.9	**1.0**	58.9	**1.1**	58.9	**2.8**	45.8	**2.6**	45.8
NMIJ			**-17.6**	31.6	**-14.0**	31.6	**-11.9**	31.6	**-12.2**	31.9	**-9.4**	31.9

Frequency→	8 Hz		10 Hz		12.5 Hz		16 Hz		20 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$		in $mV/(m/s^2)•10^{-2}$	
NIM	**3.7**	15.9	**3.0**	15.9	**2.4**	15.9	**2.9**	15.9	**2.2**	15.9
NIMT	**1.7**	45.8	**2.0**	45.9	**2.4**	45.9	**0.9**	45.9	**1.2**	45.9
NMIJ	**-9.3**	31.9	**-8.0**	32.0	**-6.6**	32.0	**-7.1**	32.0	**-5.8**	32.0

Results of horizontal voltage sensitivities of the SE-1022:

Frequency→	0.5 Hz		0.63 Hz		0.8 Hz		1 Hz		1.25 Hz		1.6 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**17.1**	19.5	**15.0**	19.7	**12.7**	20.2	**8.2**	19.8	**6.9**	19.9	**9.5**	20.2
CMS	**87.1**	324.4	**92.0**	336.9	**83.7**	311.7	**117.2**	287.3	**89.9**	286.7	**110.5**	287.1
NMIA	**-8.9**	19.5	**-5.0**	19.6	**-5.3**	20.2	**-2.8**	19.7	**-1.1**	19.8	**-1.5**	20.1
NMISA	**-22.9**	33.8	**-18.0**	33.9	**-16.3**	34.2	**-12.8**	34.0	**-10.1**	34.0	**-9.5**	34.2
NMIJ	**-0.9**	247.6	**-35.0**	85.2	**-15.3**	98.0	**-19.8**	122.8	**-23.1**	85.3	**-21.5**	47.3
KRISS	**9.1**	60.1	**3.0**	60.1	**0.7**	34.3	**1.2**	47.3	**-0.1**	47.3	**2.5**	47.4

Results of horizontal voltage sensitivities of the SE-1022 (continued):

Frequency→	2 Hz		2.5 Hz		3.15 Hz		4 Hz		5 Hz		6.3 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**7.2**	20.2	**7.0**	20.1	**4.0**	20.3	**6.8**	20.3	**8.3**	20.3	**8.8**	20.3
CMS	**78.2**	286.5	**38.0**	273.1	**94.0**	73.6	**76.8**	73.4	**17.3**	60.4	**17.8**	60.4
NMIA	**-3.8**	20.2	**-5.0**	20.0	**-9.0**	20.2	**-6.2**	20.2	**-5.7**	20.3	**-5.2**	20.3
NMISA	**-11.8**	34.3	**-12.0**	34.2	**-6.0**	34.3	**-13.2**	34.3	**-2.7**	34.4	**-2.2**	34.4
NMIJ	**-35.8**	85.3										
KRISS	**9.2**	34.3	**7.0**	34.2	**-6.0**	34.3	**-7.2**	34.3	**-9.7**	34.3	**-12.2**	34.3

Frequency→	8 Hz		10 Hz		12.5 Hz		16 Hz		20 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab *i* ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**8.5**	20.0	**9.4**	20.0	**8.8**	20.0	**6.5**	20.0	**10.8**	20.1
CMS	**24.5**	60.3	**58.4**	60.5	**37.8**	60.4	**66.5**	60.6	**36.8**	60.5
NMIA	**-6.5**	20.0	**-9.6**	20.0	**-6.2**	20.0	**-8.5**	20.0	**-7.2**	20.0
NMISA	**-5.5**	34.2	**-11.6**	34.1	**-12.2**	34.1	**-13.5**	34.2	**-13.2**	34.2
NMIJ										
KRISS	**-13.5**	47.3	**-15.6**	47.3	**-13.2**	47.3	**-10.5**	47.4	**-14.2**	47.4

Results of vertical voltage sensitivities of the SE-1022:

Frequency→	0.5 Hz		0.63 Hz		0.8 Hz		1 Hz		1.25 Hz		1.6 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab i ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**1.0**	7.8	**1.2**	7.9	**1.2**	7.9	**0.8**	9.2	**0.6**	9.2	**0.6**	9.2
NIMT	**-9.0**	70.5	**-10.8**	70.5	**-10.8**	70.5	**-5.2**	57.5	**-3.4**	57.5	**-3.4**	57.5

Frequency→	2 Hz		2.5 Hz		3.15 Hz		4 Hz		5 Hz		6.3 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab i ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**0.7**	9.2	**8.0**	15.2	**6.3**	15.2	**5.8**	15.2	**4.9**	15.9	**4.0**	15.9
NIMT	**-4.3**	57.5	**3.0**	58.8	**1.3**	58.8	**0.8**	58.8	**1.9**	45.8	**2.0**	45.8
NMIJ			**-19.0**	31.5	**-14.7**	31.6	**-13.2**	31.6	**-12.1**	31.9	**-10.0**	31.9

Frequency→	8 Hz		10 Hz		12.5 Hz		16 Hz		20 Hz	
	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i	D_i	U_i
Lab i ↓	in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}		in mV/(m/s^2)•10^{-2}	
NIM	**3.4**	15.9	**3.0**	15.9	**2.9**	15.9	**2.1**	15.9	**1.7**	15.9
NIMT	**1.4**	45.8	**2.0**	45.8	**0.9**	45.8	**2.1**	45.8	**2.7**	45.9
NMIJ	**-8.6**	31.9	**-8.0**	31.9	**-7.1**	31.9	**-5.9**	32.0	**-5.3**	32.0