State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer"(SE "Ukrmetrteststandard")

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Final Report
on COOMET Key Comparison of AC/DC voltage transfer references (COOMET.EM-K6a)

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Participants of comparisons:
SE "Ukrmetrteststandard", Ukraine
VNIIM, Russia
GSM, Azerbaijan
BelGIM, Republic of Belarus
INM, Romania

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Table of contents

1 Introduction

The COOMET Key Comparison (KC) of AC/DC voltage transfer references (comparison identifier – COOMET.EM-K6a) was conducted in the framework of COOMET 566/UA/12project from 2013 to 2014.

This project was conducted between countries which are member laboratories of regional metrology organization COOMET. In this comparison take part five national metrology institutes (NMI): SE “Ukrmetrteststandard” – UMTS (Ukraine); VNIIM (Russia); SMS (Azerbaijan); BelGIM (Belarus); INM (Romania).

Proposed to link the results from COOMET.EM-K6a to the CCEM-K6a [1] carried out between 1993 and 1999. VNIIM (Russia) is linking NMIs as far as they participated in CCEM-K6a.

The State Enterprise “All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer” (SE “Ukrmeterteststandard”), Ukraine was the pilot laboratory.

2 Participants

List of participating NMIs, countries and regional organizations is show in Table 1.

Table 1 List of participating NMIs, countries and regional organizations

NMI	Country	Regional organization
UMTS – State Enterprise “All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer” (SE “Ukrmeterteststandard”) **– pilot**	Ukraine	COOMET
VNIIM – D.I. Mendeleyev Institute for Metrology	Russia	COOMET/APMP
SMS – State Metrological Service	Azerbaijan	COOMET
BelGIM – Belarusian State Institute of Metrology	Belarus	COOMET
INM – National Institute of Metrology	Romania	COOMET/EURAMET

3 Traveling standard and measurement instructions

3.1 Description of traveling standard

Traveling AC-DC-transfer standard is the Single Junction Thermal Converter type ПНТЭ-6А serial No 1848 (thereinafter – the traveling standard ПНТЭ-6А). The traveling standard ПНТЭ-6А have manufactured as three-dimensional construction, in which used the thermocouple type ТВБ-2 (vacuum contact-free thermocouple, design 2). The short specification of the traveling standard ПНТЭ-6А is given bellow:

input voltage	3	V;
output voltage	5	mV;
input resistance	1000	Ω;
output resistance	20	Ω.

The traveling standard ПНТЭ-6А has a square-law response of it's output thermocouple voltage from the heater current.

The general form of the traveling standard ПНТЭ-6А is shown in Figure 1. The coaxial connector for input voltage of the traveling standard ПНТЭ-6А is completed by detachable adapter in order to provide adaptation to usual connector N-type (female). The output voltage of the traveling standard ПНТЭ-6А is brought to the clip connectors "+" and "–". The clip connector with marking "⊥" is located nearly and has the electrical link with case of the traveling standard ПНТЭ-6А. The transport suitcase and the traveling standard ПНТЭ-6А are shown in Figure 2.

Figure 1

Figure 2

3.2 Measurements

After receiving of the traveling standard by participating NMIs it stabilized during one day at measurement conditions and in disconnection stay.

Measurement conditions:
temperature: 23 °C ±3 °C;
relative humidity: between 30 % and 70 %;

The thermo-electric transfer of the travelling standard ПНТЭ-6А shuts out exceeding of input voltage more than on 5%, therefore before his plugging in the proper electric circuits it is necessary to provide defense, for example, automatic blocking which does not allow to set (or to activate) value more then 3,1 V.

The coaxial connector of the travelling standard ПНТЭ-6А is intended for connecting of voltage 3 V from the source of AC voltage $U_{\sim}$ or from the source of DC voltage $U_{=}$. Terminals with marking of "+", "–" and "⊥" is intended for connecting of measuring device – the high resolution millivoltmeter.

Before performing of the measuring procedure the travelling standard ПНТЭ-6А must be maintained in active mode (under input voltage 3 V) during 2 h with maintenance of the stable ambient temperature. The travelling standard ПНТЭ-6А shall to protect from the streams of ambient air during its functioning.

4 Uncertainty of measurement

The uncertainty was calculated following the ISO/IEC Guide 98-3:2008 "Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement" (GUM): standard uncertainties, degrees of freedom, correlations, scheme for the uncertainty evaluation.

All contributions to the uncertainty of measurement were listed separately in the report and identified as either Type A or Type B uncertainties. Uncertainties were evaluated at the level of one standard uncertainty and the number of effective degrees of freedom is to be reported.

5 Traceability to the SI

The traceability to the SI of standards was provided to pilot NMI. The participating NMIs made measurements of this traveling capacitor in terms of either their own calculable capacitor or a quantum Hall reference standard, or have traceability to other laboratories. This meant that there were a number of independent measurements of AC/DC voltage transfer which enabled the representation of the farad in those countries were compared.

The traceability route for the primary standard of AC/DC voltage transfer for each NMI is given in Table 2.

Table 2 Traceability route for each participating NMI

NMI	Country	Traceability Route
VNIIM	Russia	VNIIM
UMTS	Ukraine	PTB
SMS	Azerbaijan	PTB
BelGIM	Belarus	PTB
INM	Romania	PTB

6 Behavior of the traveling standard

The UMTS as pilot laboratory has performed repeated measurements on the traveling standard (ПНТЭ-6А) during the course of this comparison.

As the value of the AC/DC voltage transfer difference are time-dependent it was measured before and after each visit so that a drift curve for each one could be established. But the traveling standard ПНТЭ-6А have shown good long-term stability over this time, and no drift during this measurements could be detected. Some differences at the different measurement dates do not exceed the value of standard uncertainty.

7 Reported results

7.1 General information and data

A full measurement report containing all relevant data and uncertainty estimates was forwarded to the coordinator within six weeks of completing measurement of the transducer. The report included the traceability to the SI, and the results, associated uncertainty and number of degrees of freedom.

List of measurement dates of the NMI participants is show in Table 3.

Table 3 List of measurement dates of the NMI participants

NMI	Measurement dates	Frequency, kHz				
		0,02	1	20	100	1000
UMTS1, Ukraine	14–16.05.2013	yes	yes	yes	yes	yes
VNIIM, Russia	20–24.05.2013	yes	yes	yes	yes	yes
UMTS2, Ukraine	03–05.06.2013	yes	yes	yes	yes	yes
SMS, Azerbaijan	18–21.06.2013	yes	yes	yes	yes	no
UMTS3, Ukraine	08–11.07.2013	yes	yes	yes	yes	yes
BelGIM, Belarus	23–24.07.2013	no	yes	yes	yes	no
UMTS4, Ukraine	10–12.09.2013	yes	yes	yes	yes	yes
INM, Romania	06–17.01.2014	yes	yes	yes	yes	yes
UMTS5, Ukraine	18–20.03.2014	yes	yes	yes	yes	yes

Additional parameters for measurement of the NMI participants are show in Table 4. The AD-DC voltage transfer differences (δ) and theirs expanded uncertainties (*U*) reported by the NMI participants at frequencies of 20 Hz, 1 kHz, 20 kHz, 100 kHz, and 1 MHz shown on Table 5 (Appendixes 1 and 2). In Technical protocol of comparison (Appendix 3) and KCDB SMU (Slovakia) is marked, but those NMIs did not take part in comparison in the sequel.

Table 4 Parameters for measurement of the NMI participants

Parameter	Value
VNIIM, Russia	
Ambient temperature, °C	23 ±1
Relative humidity, %	30 … 50

Parameter	Value
UMTS, Ukraine	
Ambient temperature, °C	23 ±1
Relative humidity, %	30 … 50
SMS, Azerbaijan	
Ambient temperature, °C	23 ±1
Relative humidity, %	40 … 60
BelGIM, Belarus	
Ambient temperature, °C	23 ±1
Relative humidity, %	40 … 60
INM, Romania	
Ambient temperature, °C	23 ±1
Relative humidity, %	30 … 50

Table 5Measured results for NMI participants (10^{-6})

NMI	20 Hz		1 kHz		20 kHz		100 kHz		1 MHz	
	δ	*U*	δ	*U*	δ	*U*	δ	*U*	δ	*U*
VNIIM	2.7	8.3	–0.8	2.5	–1.5	2.8	–5.0	4.0	–57	28.2
UMTS	–8.0	10.4	0.3	4.4	–1.6	4.4	–10.0	8.4	–71	40
SMS	22.0	18.0	7.4	14.2	12.0	22.0	–25.0	25.6	–	
BelGIM	–	–	4.4	24.0	10.0	29.0	19.0	139.0	–	–
INM	3.7	3.0	1.5	3.0	–3.1	3.0	–12.8	12	–21	22

7.2 Calculation of the key comparison reference values and their uncertainties

The key comparison reference values (KCRV) x_{ref} are calculated as the mean of participant results with COOMET.EM-K6a data are given by

$$x_{ref} = \sum_{i=1}^{N} \frac{x_i}{u_c^2(x_i)} \Bigg/ \sum_{i=1}^{N} \frac{1}{u_c^2(x_i)} \qquad (1)$$

with combine standard uncertainties

$$u_c^2(x_{ref}) = 1 \Big/ \sum_{i=1}^{N} \frac{1}{u_c^2(x_i)} \, . \tag{2}$$

In cases the calculated simple weighted mean of all results presented in Table 6.

Table 6 Reference values and its expanded uncertainties (k = 2) (10^{-6})

20 Hz		**1 kHz**		**20 kHz**		**100 kHz**		**1 MHz**	
x_{ref}	U_{ref}	x_{ref}	U_{ref}	x_{ref}	U_{ref}	x_{ref}	U_{ref}	x_{ref}	U_{ref}
3.22	5.38	0.30	3.48	–1.98	3.69	–6.81	6.14	–40.38	31.83

7.3 Degrees of equivalence of NMI participants

Only one value is reported for NMI participants. Degrees of equivalence of the NMI participants are reported with respect to the measurement at 20 Hz, 1 kHz, 20 kHz, 100 kHz, and 1 MHz.

The degrees of equivalence of i-th NMI and its combined standard uncertainties with respect to the KCRV is estimated as

$$D_i = x_i - x_{ref} \, . \tag{3}$$

$$u_c^2(D_i) = u_c^2(x_i) + u_c^2(x_{ref}) \, . \tag{4}$$

The degrees of equivalence of the NMI participants and its expanded uncertainties $U(D_i)$ (k = 2) with respect to the KCRV at 20 Hz, 1 kHz, 20 kHz, 100 kHz, and 1 MHz are also presented in Tables 7 and the graphs in Figures 1–5.

Table 7 Degrees of equivalence of the NMI participants (10^{-6})

NMI	**20 Hz**		**1 kHz**		**20 kHz**		**100 kHz**		**1 MHz**	
	D_i	$U(D_i)$	D_i	$U(D_i)$	D_i	$U(D_i)$	D_i	$U(D_i)$	D_i	$U(D_i)$
VNIIM	–0.5	9.89	–1.1	4.3	0.5	4.6	1.8	7.3	–16.6	42.5
UMTS	–11.2	11.71	0.0	5.6	0.4	5.7	–3.2	10.4	–30.6	51.1
SMS	18.8	18.79	7.1	14.6	14.0	22.3	–18.2	26.3	–	–
BelGIM	–	–	4.1	24.3	12.0	29.2	25.8	139.1	–	–
INM	0.5	6.16	1.2	4.6	–1.1	4.8	–6.0	8.6	19.4	38.7

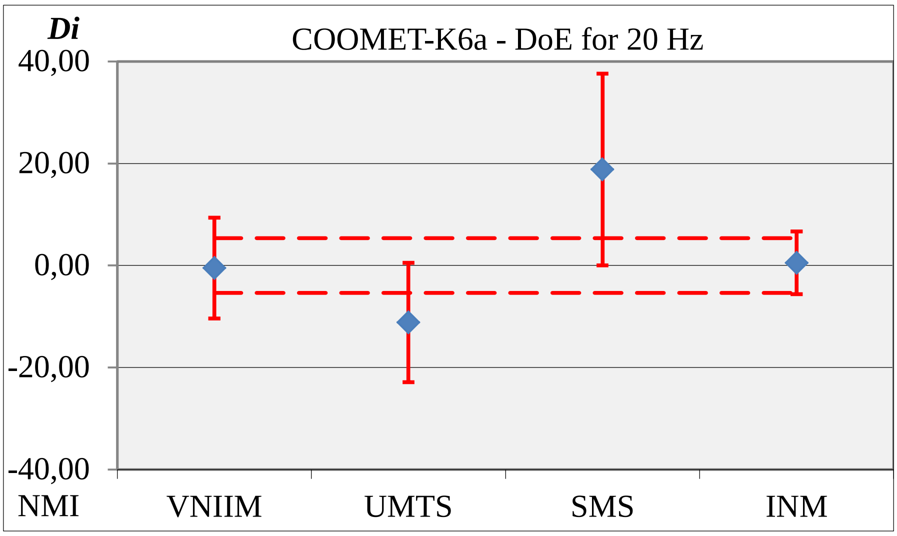

Figure 1 Degree of equivalence for NMI participants at 20 Hz

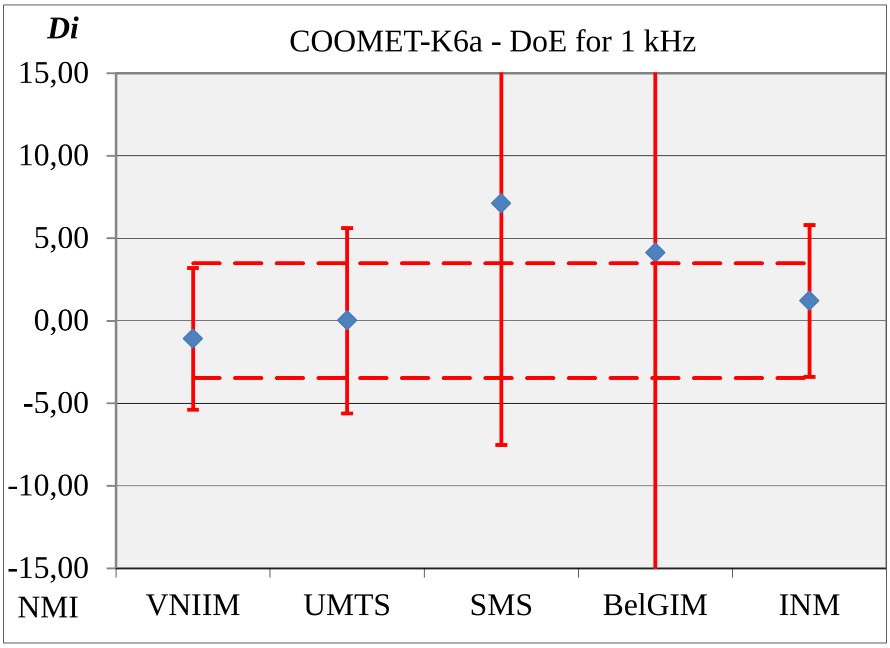

Figure 2 Degree of equivalence for NMI participants at 1kHz

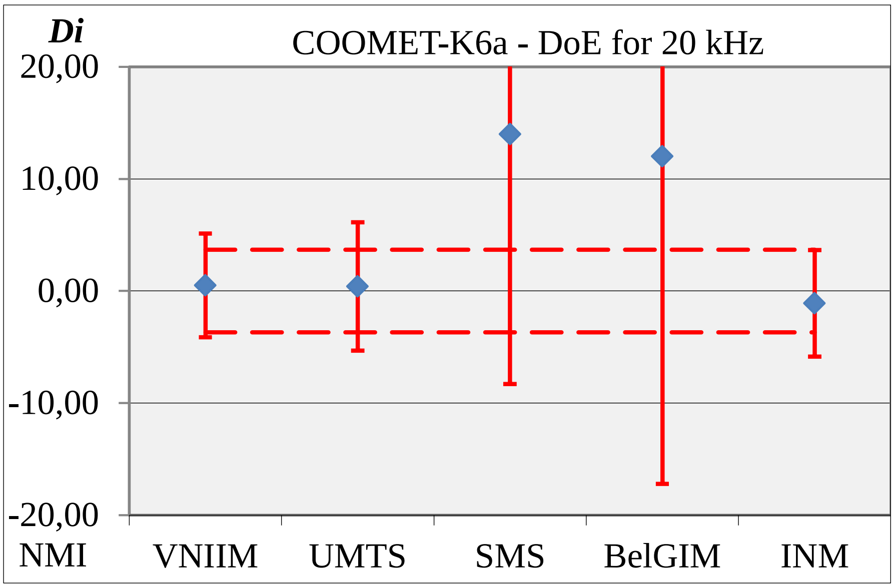

Figure 3 Degree of equivalence for NMI participants at 20kHz

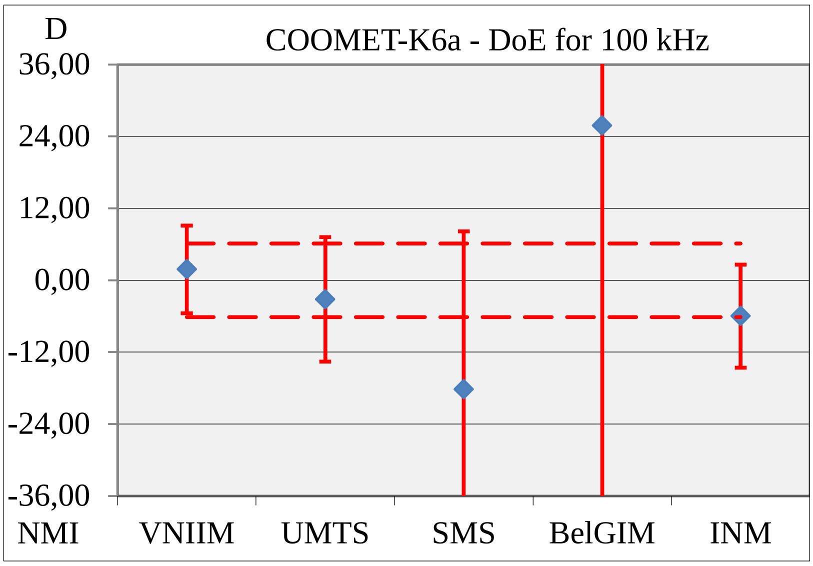

Figure 4 Degree of equivalence for NMI participants at 100kHz

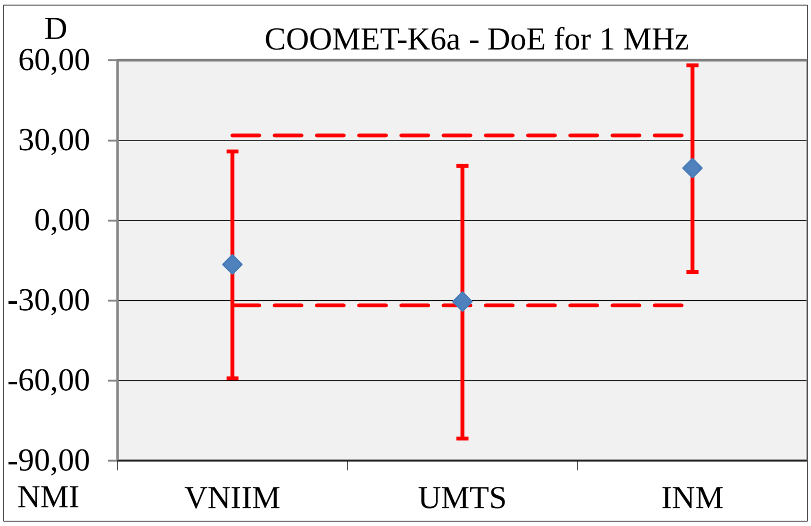

Figure 5 Degree of equivalence for NMI participants at 1 MHz

The principal results of this comparison are the pair-wise degrees of equivalence and the degrees of equivalence with respect to the KCRV of CCEM-K6a.

The pair degrees of equivalence of *i*-th NMI and *j*-th NMI participants D_{ij} and its expanded uncertainties $U(D_{ij})$ (k = 2) with respect to the KCRV at 1 kHz, 20 kHz, 100 kHz, and 1 MHz are shown in Tables 8 (*Azerbaijan is not significant of CIPM MRA*).

Pair degree of equivalence of *i*-th NMI and *j*-th NMI participants D_{ij} with combined standard uncertainty $u_c(D_{ij})$ are estimated by

$$D_{ij} = x_i - x_j \,. \tag{5}$$

$$u_c^2(D_{ij}) = u_c^2(x_i) + u_c^2(x_j)\,. \tag{6}$$

Table 8 Pair degrees of equivalence for NMI participants

1 kHz			**UMTS**		**BelGIM**		**INM**	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
UMTS	0.0	4.4	0.0	0.0	4.1	24.4	1.2	5.3
BelGIM	4.1	24.0	–4.1	24.4	0.0	0.0	–2.9	24.2
INM	1.2	3.0	–1.2	5.3	2.9	24.2	0.0	0.0
20 kHz			**UMTS**		**BelGIM**		**INM**	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
UMTS	0.4	5.0	0.0	0.0	11.6	29.5	–1.5	6.3
BelGIM	12.0	29.1	–11.6	29.5	0.0	0.0	–13.1	29.4
INM	–1.1	3.9	1.5	6.3	13.1	29.4	0.0	0.0
100 kHz			**UMTS**		**BelGIM**		**INM**	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
UMTS	–3.2	9.3	0.0	0.0	29.0	139.3	–2.8	15.7
BelGIM	25.8	139.0	–29.0	139.3	0.0	0.0	–31.8	139.6
INM	–6.0	12.6	2.8	15.7	31.8	139.6	0.0	0.0
1 MHz			**UMTS**		**INM**			
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)		
UMTS	–30.6	41.6	0.0	0.0	50.0	48.4		
INM	19.4	24.8	–50.0	48.4	0.0	0.0		

7.4 Proposal for linking to CCEM-K6a key comparison and degrees of equivalence of NMI participants

We propose that the results COOMET.EM-K6a be linked to CCEM-K6aat 1 kHz, 20 kHz, 100 kHz, and 1 MHz with using a method similar to that used to linking EUROMET.EM-K6a to CCEM-K6a, SIM.EM-K6a to CCEM-K6a, and APMP.EM-K6a to CCEM-K6a, SIM.EM-K6.1to CCEM-K6a [2–5].

The degrees of equivalence of *i*-th NMI with respect to linking to CCEM-K6a is estimated as

$$d_i = D_i + \Delta \, . \qquad (7)$$

where:

D_i – result from COOMET.EM-K6a for a NMI participant in COOMET.EM-K6a only;

d_i – best estimate of result from NMI*i* to linking to CCEM-K6a.

Measurements from the linking NMIs provide estimates

$$\Delta_{iLINK} = d_{iLINK} - D_{iLINK} \tag{8}$$

for the correction Δ.

where:

d_{iLINK} – result from CCEM-K6a for a linking NMI;

D_{iLINK} – result from COOMET.EM-K6a for a linking NMI.

The linking NMIis VNIIM. No significant changes to the method of measurement used in CCEM-K6a and COOMET.EM-K6a were made by VNIIM.

Table 9 lists the values of the quantities used in the calculation.

Table 9 CCEM-K6a and COOMET.EM-K6a comparison results
and expanded uncertainties for linking NMI, (10^{-6})

Linking NMI (VNIIM)	d_{iLINK}	D_{iLINK}	Δ_{iLINK}	U_T
1 kHz	0.2	–0.8	1.0	0.4
20 kHz	1.0	–1.5	2.5	0.52
100 kHz	4.2	–5.0	9.2	1.0
1 MHz	103.0	57.0	46.0	6.7

The best estimate of the result from NMI *i* had it participated in CCEM-K6a is calculated using (7). The standard uncertainty is calculated as:

$$u^2(d_i) = u^2(D_i) + u^2(\Delta) = u^2(D_i) + s^2(\Delta) + u^2(m_{ref}). \tag{9}$$

where: $u(m_{ref})$ = 0.018 is the uncertainty in $u(m_{ref})$, the CCEM-K6a KCRV. The expanded uncertainty is $U(d_i) = k_{d_i} u(d_i)$, where is chosen k_{d_i} = 2 to give 95 % coverage.

The calculated degrees of equivalence with respect to CCEM-K6aKCRV are tabulated in d_i Table 10 (*Azerbaijan is not significant of CIPM MRA*).

Table 10 Proposed degrees of equivalence for NMI participants
relative to theCCEM-K6a KCRV, (10^{-6})

NMI	**1 kHz**		**20 kHz**		**100 kHz**		**1 MHz**	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
VNIIM	–	–	–	–	–	–	–	–
UMTS	0.0	4.4	0.4	5.0	–3.2	9.3	–30.6	41.6
BelGIM	4.1	24.0	12.0	29.1	25.8	139.0	–	–
INM	1.2	3.0	–1.1	3.9	–6.0	12.6	19.4	24.8

The declared uncertainties are judged as confirmed if the following equation is satisfied

$$\left|d_i\right| < 2u_c(d_i)\,. \qquad (10)$$

Degrees of equivalence D_i with respect to the CCEM-K6a KCRV for CCEM-K6a (red diamonds), EUROMET.EM-K6a (green triangle),SIM.EM-K6a (blue circles),APMP.EM-K6a (orange squares), SIM.EM-K6.1 (pink triangle), and COOMET.EM-K6a (brown squares) are shown on Figure 6–9.

Where NMI *i* participated only in COOMET.EM-K6a and NMI *j* participated in COOMET.EM-K6a, the pair-wise degrees of equivalence d_{ij} with its uncertainties are those calculated in Section 7.3, that is.

$$d_{ij} = D_{ij} \text{ and } U\left(d_{ij}\right) = U\left(D_{ij}\right). \qquad (11)$$

Where NMI *i* participated only in COOMET.EM-K6a and NMI *j* participated in CCEM-K6a or EUROMET.EM-K6a or SIM.EM-K6a or APMP.EM-K6a or SIM.EM-K6.1 but not in COOMET.EM-K6a, then

$$d_{ij} = d_i - d_j\,. \qquad (12)$$

$$u^2\left(d_{ij}\right) = u^2\left(d_i\right) + u^2\left(d_j\right) - 2u^2\left(m_{ref}\right) - 2u_r^2\,. \qquad (13)$$

where u_r is the standard uncertainty associated with a common reference standard (relevant only if laboratory *i* derives its traceability from NMI *j*, or if NMI*i* and NMI *j* both derive.

Proposed degrees of equivalence for participants of COOMET.EM-K6a with participants in CCEM-K6a (red), EUROMET.EM-K6a (green),SIM.EM-K6a (blue),APMP.EM-K6a (orange),SIM.EM-K6.1 (pink), and COOMET.EM-K6a (brow) are shown on Table 11.

8 Summary

A key comparison of AC/DC voltage transfer references at 20 Hz, 1 kHz, 20 kHz, 100 kHz, and 1 MHz has been conducted between participating COOMET member NMIs. In general there is good agreement between NMI participants for this quantity. It is expected that this comparison will be able to provide support for participants' entries in Appendix C of the CIPM MRA. Proposal for linking to CCEM-K6a key comparison and degrees of equivalence of NMI participants at 1 kHz, 20 kHz, 100 kHz, and 1 MHz was made.

References

[1] M.Klonz. Final report: CCE comparison of ac-dc voltage transfer standards at the lowest attainable level of uncertainty. *Metrologia* 1997.**34**.291.

[2] T.Funck, I.Hadzhieva. Draft B report of EUROMET.EM-K6.a. *Metrologia*2007.**44.** 01012.

[3] S. Campos et al. Final report: SIM regional comparison of ac–dc voltage transfer difference (SIM.EM.K6a, SIM.EM-K9 and SIM.EM-K11). *Metrologia* 2009.**46.** 01004.

[4] I.Budovsky. Final report on APMP.EM-K6.a: APMP international comparison of ac–dc transfer standards at the lowest attainable level of uncertainty. *Metrologia*.2010.**47.** 01018.

[5] R. de Barros e Vasconcellos, A.Poletaeff.Final report on SIM bilateral INMETRO–LNE comparisons SIM.EM-K6.1 and SIM.EM-K9.1: AC–DC voltage transfer difference. *Metrologia.* 2014.**51.** 01001.

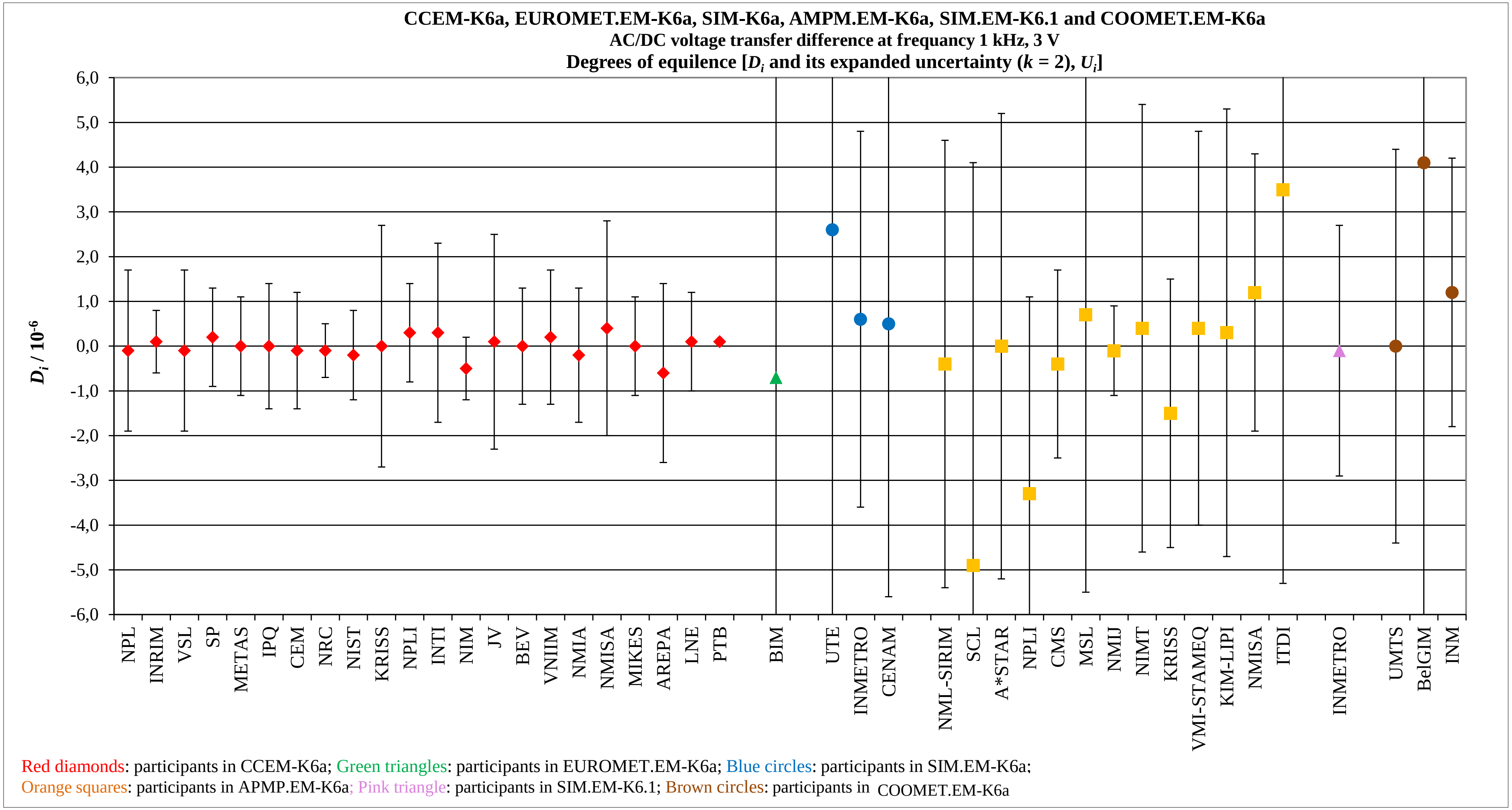

Figure 6 Degrees of equivalence D_i with respect to the CCEM-K6a key comparison reference value at 1 kHz

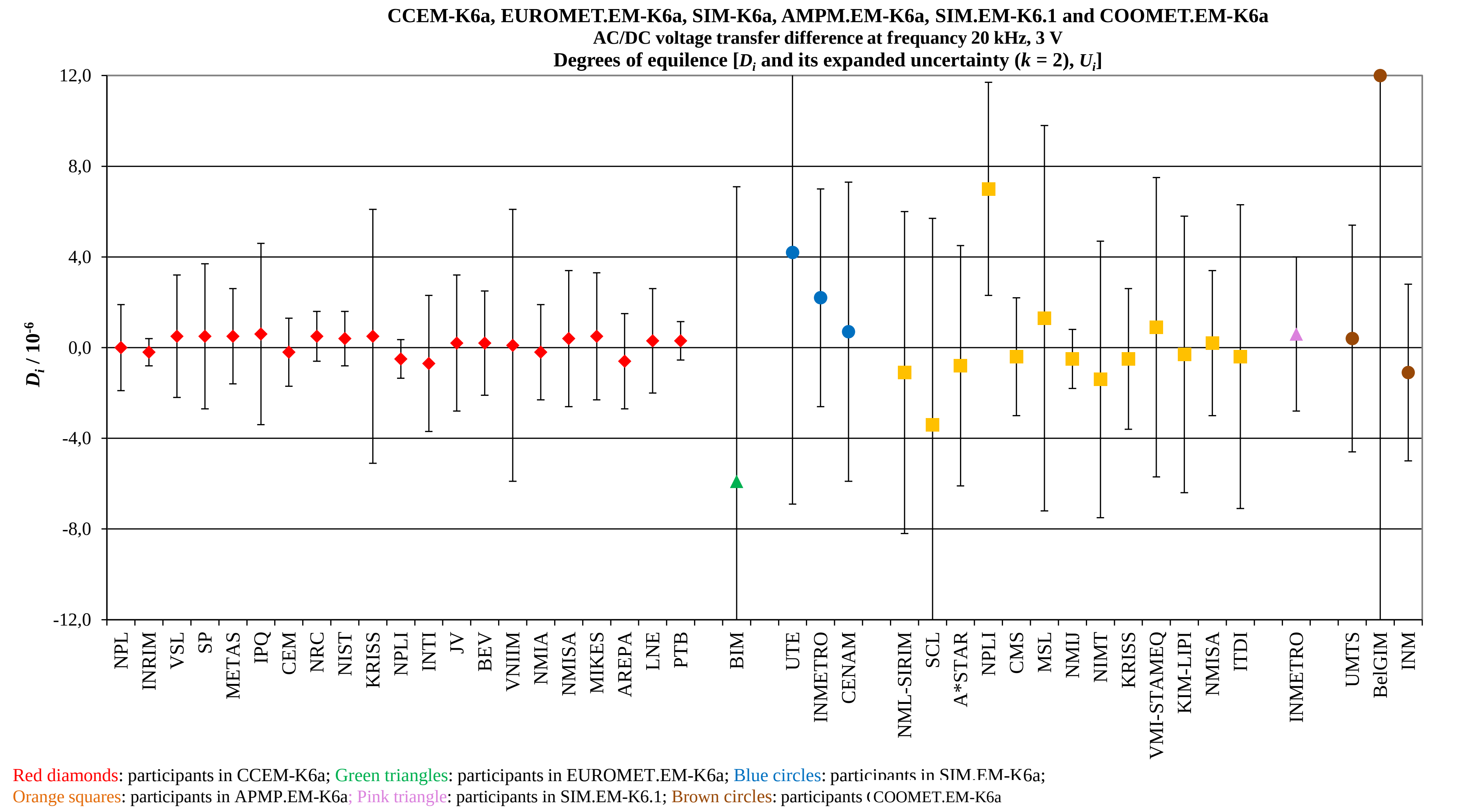

Figure 7 Degrees of equivalence D_i with respect to the CCEM-K6a key comparison reference value at 20 kHz

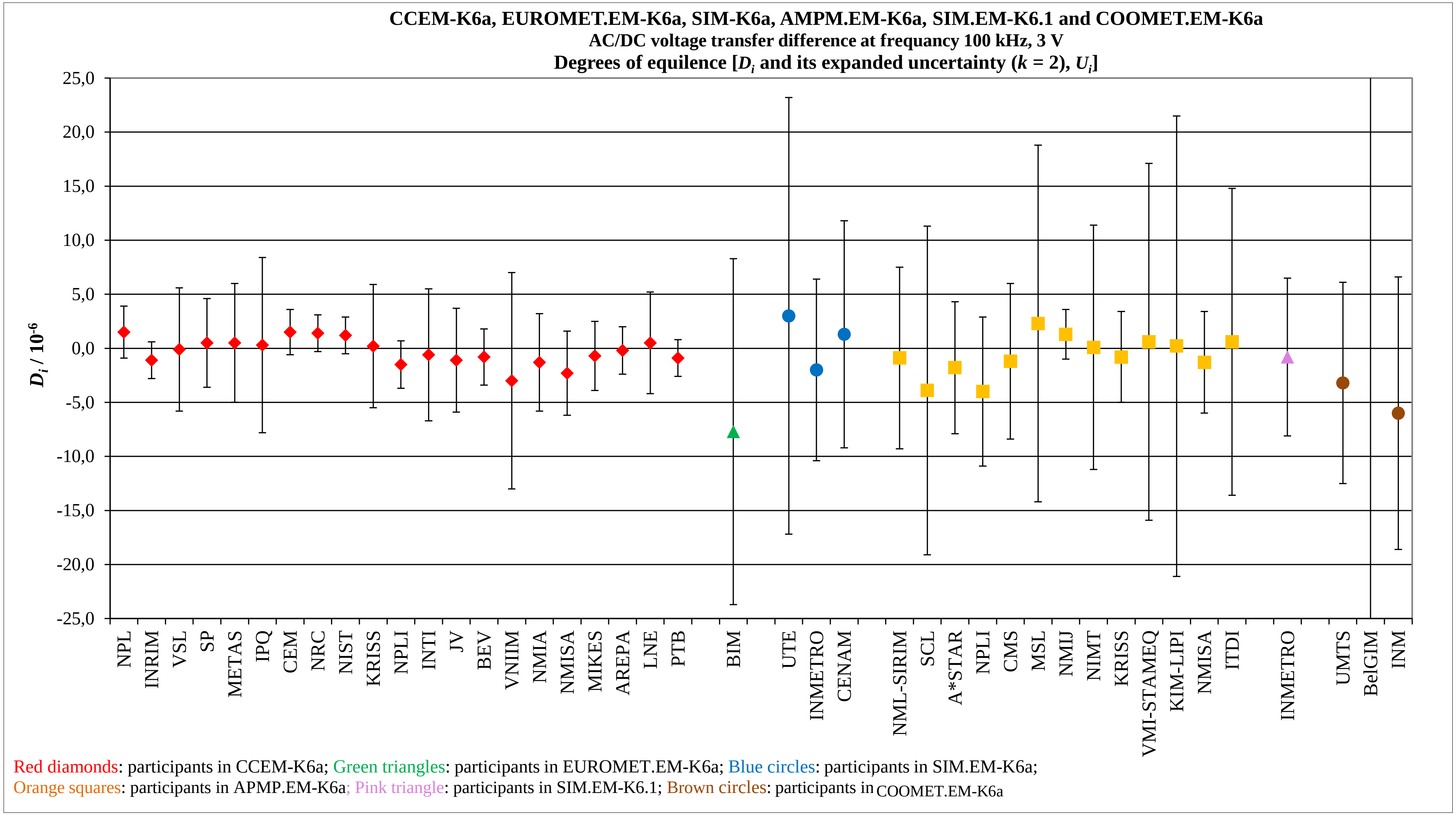

Figure 8 Degrees of equivalence D_i with respect to the CCEM-K6a key comparison reference value at 100 kHz

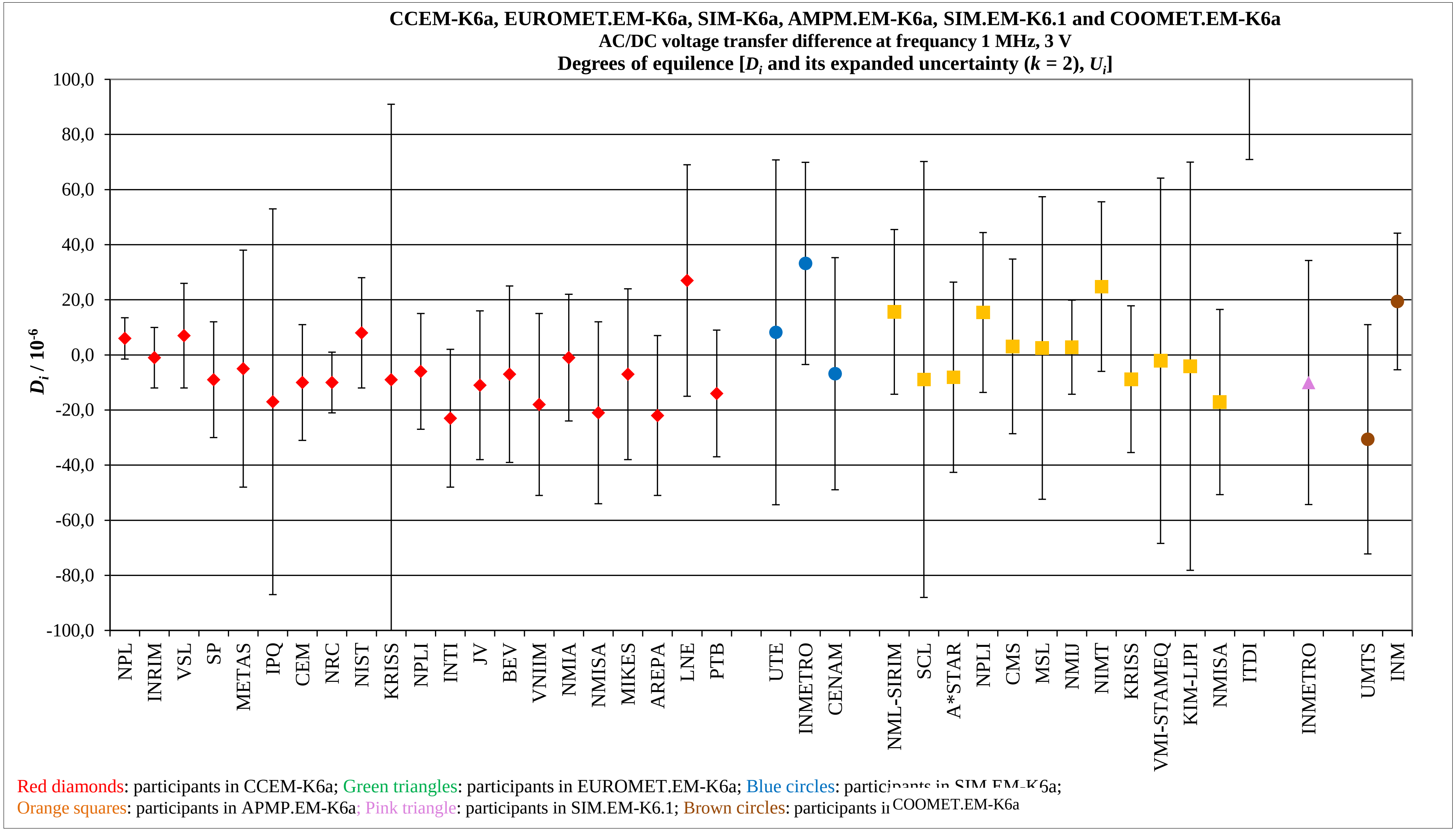

Figure 9 Degrees of equivalence D_i with respect to the CCEM-K6a key comparison reference value at 1 MHz

Table 11 Proposed degrees of equivalence for participants of COOMET.EM-K6a with participants in CCEM-K6a (red),EUROMET.EM-K4 (blue),SIM.EM-K6a (green), APMP.EM-K6a (orange), SIM.EM-K6.1 (pink), and COOMET.EM-K6a (brow)

1 kHz			**UMTS**		**BelGIM**		**INM**	
NMI	*Di*	*U(Di)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*
NPL	–0.10	1.80	0.10	4.75	4.20	24.07	1.30	3,50
INRIM	0.10	0.70	–0.10	4.46	4.00	24.01	1.10	3,08
VSL	–0.10	1.80	0.10	4.75	4.20	24.07	1.30	3,50
SP	0.20	1.10	–0.20	4.54	3.90	24.03	1.00	3,19
METAS	0.00	1.10	0.00	4.54	4.10	24.03	1.20	3,19
IPQ	0.00	1.40	0.00	4.62	4.10	24.04	1.20	3,31
CEM	–0.10	1.30	0.10	4.59	4.20	24.04	1.30	3,27
NRC	–0.10	0.60	0.10	4.44	4.20	24.01	1.30	3,06
NIST	–0.20	1.00	0.20	4.51	4.30	24.02	1.40	3,16
KRISS	0.00	2.70	0.00	5.16	4.10	24.15	1.20	4,04
NPLI	0.30	1.10	–0.30	4.54	3.80	24.03	0.90	3,19
INTI	0.30	2.00	–0.30	4.83	3.80	24.08	0.90	3,61
NIM	–0.50	0.70	0.50	4.46	4.60	24.01	1.70	3,08
JV	0.10	2.40	–0.10	5.01	4.00	24.12	1.10	3,84
BEV	0.00	1.30	0.00	4.59	4.10	24.04	1.20	3,27
VNIIM	0.20	1.50	–0.20	4.65	3.90	24.05	1.00	3,35
NMIA	–0.20	1.50	0.20	4.65	4.30	24.05	1.40	3,35
NMISA	0.40	2.40	–0.40	5.01	3.70	24.12	0.80	3,84
MIKES	0.00	1.10	0.00	4.54	4.10	24.03	1.20	3,19
AREPA	–0.60	2.00	0.60	4.83	4.70	24.08	1.80	3,61
LNE	0.10	1.10	–0.10	4.54	4.00	2403	1.10	3,19
PTB	0.10	0.00	–0.10	4.40	4.00	24.00	1.10	3,00
BIM	–0.70	16.00	0.70	16.59	4.80	28.84	1.90	16,28
UTE	2.60	11.10	–2.60	11.94	1.50	26.44	–1.40	11,50
INMETRO	0.60	4.20	–0.60	6.08	350	24.36	0.60	5,16
CENAM	0.50	6.10	–0.50	7.52	3.60	24.76	0.70	6,80
NML-SIRIM	–0.40	5.00	0.40	6.66	4.50	24.52	1.60	5,83
SCL	–4.90	9.00	4.90	10.02	900	25.63	6.10	9,49
A*STAR	0.00	5.20	0.00	6.81	4.10	24.56	1.20	6,00
NPLI	–3.30	4.40	3.30	6.22	740	24.40	4.50	5,33
CMS	–0.40	2.10	0.40	4.88	4.50	2409	1.60	3,66
MSL	0.70	6.20	–0.70	7.60	3.40	24.79	0.50	6,89
NMIJ	–0.10	1.00	0.10	4.51	4.20	24.02	1.30	3,16
NIMT	0.40	5.00	–0.40	6.66	3.70	2452	0.80	5,83
KRISS	–1.50	3.00	1.50	5.33	5.60	24.19	2.70	4,24

1 kHz			UMTS		BelGIM		INM	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
VMI-STAMEQ	0.40	4.40	–0.40	6.22	3.70	24.40	0.80	5.33
KIM-LIPI	0.30	5.00	–0.30	6.66	3.80	24.52	0.90	5.83
NMISA	1.20	3.10	–1.20	5.38	2.90	24.20	0.00	4.31
ITDI	3.50	8.80	–3.50	9.84	0.60	25.56	–2.30	9.30
INMETRO	–0.10	2.80	0.10	5.22	4.20	24.16	1.30	4.10
UMTS	0.0	4.4	0.0	0.0	4.1	24.4	1.2	5.3
BelGIM	4.1	24.0	–4.1	24.4	0.0	0.0	–2.9	24.2
INM	1.2	3.0	–1.2	5.3	2.9	24.2	0.0	0.0
20 kHz			**UMTS**		**BelGIM**		**INM**	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
NPL	0.00	1.90	0.40	5.35	12.00	29.16	–1.10	4.34
INRIM	–0.20	0.60	0.60	5.04	12.20	29.11	–0.90	3.95
VSL	0.50	2.70	–0.10	5.68	11.50	29.22	–1.60	4.74
SP	0.50	3.20	–0.10	5.94	11.50	29.28	–1.60	5.04
METAS	0.50	2.10	–0.10	5.42	11.50	29.18	–1.60	4.43
IPQ	0.60	4.00	–0.20	6.40	11.40	29.37	–1.70	5.59
CEM	–0.20	1.50	0.60	5.22	12.20	29.14	–0.90	4.18
NRC	0.50	1.10	–0.10	5.12	11.50	29.12	–1.60	4.05
NIST	0.40	1.20	0.00	5.14	11.60	29.12	–1.50	4.08
KRISS	0.50	5.60	–0.10	7.51	11.50	29.63	–1.60	6.82
NPLI	–0.50	0.85	0.90	507	12.50	29.11	–0.60	3.99
INTI	–0.70	3.00	1.10	5.83	12.70	29.25	–0.40	4.92
JV	0.20	300	0.20	5.83	11.80	29.25	–1.30	4.92
BEV	0.20	2.30	0.20	5.50	11.80	29.19	–1.30	4.53
VNIIM	0.10	600	0.30	7.81	11.90	29.71	–1.20	7.16
NMIA	–0.20	2.10	0.60	5.42	12.20	29.18	–0.90	4.43
NMISA	0.40	3.00	0.00	5.83	11.60	29.25	–1.50	4.92
MIKES	0.50	2.80	–0.10	5.73	11.50	29.23	–1.60	4.80
AREPA	–0.60	210	1.00	5.42	12.60	29.18	–0.50	4.43
LNE	0.30	2.30	0.10	5.50	11.70	29.19	–1.40	4.53
PTB	0.30	0.85	0.10	5.07	11.70	29.11	–1.40	3.99
BIM	–5.90	13.00	6.30	13.93	17.90	31.87	4.80	13.57
UTE	4.20	11.10	–3.80	12.17	7.80	31.15	–5.30	11.77
INMETRO	2.20	4.80	–1.80	6.93	9.80	29.49	–3.30	6.18
CENAM	0.70	6.60	–0.30	8.28	11.30	29.84	–1.80	7.67
NML-SIRIM	–1.10	7.10	1.50	8.68	13.10	29.95	0.00	8.10
SCL	–3.40	9.10	3.80	10.38	15.40	30.49	2.30	9.90
A*STAR	–0.80	5.30	1.20	7.29	12.80	29.58	–0.30	6.58

			UMTS		BelGIM		INM	
NMI	*Di*	*U(Di)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*
NPLI	7.00	4.70	–6.60	6.86	5.00	29.48	–8.10	6.11
CMS	–0.40	2.60	0.80	5.64	12.40	29.22	–0.70	4.69
MSL	1.30	8.50	–0.90	9.86	10.70	30.32	–2.40	9.35
NMIJ	–0.50	1.30	0.90	5.17	12.50	29.13	–0.60	4.11
NIMT	–1.40	6.10	1.80	7.89	13.40	29.73	0.30	7.24
KRISS	–0.50	3.10	0.90	5.88	12.50	29.26	–0.60	4.98
VMI-STAMEQ	0.90	6.60	–0.50	8.28	11.10	29.84	–2.00	7.67
KIM-LIPI	–0.30	6.10	0.70	7.89	12.30	29.73	–0.80	7.24
NMISA	0.20	3.20	0.20	5.94	11.80	29.28	–1.30	5.04
ITDI	–0.40	6.70	0.80	8.36	12.40	29.86	–0.70	7.75
INMETRO	0.60	3.40	–0.20	6.05	11.40	29.30	–1,70	5,17
UMTS	0.4	5.0	0.0	0.0	11.6	29.5	–1.5	6.3
BelGIM	12.0	29.1	–11.6	29.5	0.0	0.0	–13.1	29.4
INM	–1.1	3.9	1.5	6.3	13.1	29.4	0.0	0.0
100 kHz			UMTS		BelGIM		INM	
NMI	*Di*	*U(Di)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*
NPL	1.50	2.40	–4.70	9.60	24.30	139.02	–7.50	12.83
INRIM	–1.10	1.70	–2.10	9.45	26.90	139.01	–4.90	12.71
VSL	–0.10	5.70	–3.10	10.91	25.90	139.12	–5.90	13.83
SP	0.50	4.10	–3.70	10.16	25.30	139.06	–6.50	13.25
METAS	0.50	5.50	–3.70	10.80	25.30	139.11	–6.50	13.75
IPQ	0.30	8.10	–3.50	12.33	25.50	139.24	–6.30	14.98
CEM	1.50	2.10	–4.70	9.53	24.30	139.02	–7.50	12.77
NRC	1.40	1.70	–4.60	9.45	24.40	139.01	–7.40	12.71
NIST	1.20	1.70	–4.40	9.45	24.60	139.01	–7.20	12.71
KRISS	0.20	5.70	–3.40	10.91	25.60	139.12	–6.20	13.83
NPLI	–1.50	2.20	–1.70	9.56	27.30	139.02	–4.50	12.79
INTI	–0.60	6.10	–2.60	11.12	26.40	139.13	–5.40	14.00
JV	–1.10	4.80	–2.10	10.47	26.90	139.08	–4.90	13.48
BEV	–0.80	2.60	–2.40	9.66	26.60	139.02	–5.20	12.87
VNIIM	–3.00	10.00	–0.20	13.66	28.80	139.36	–3.00	16.09
NMIA	–1.30	4.50	–1.90	10.33	27.10	139.07	–4.70	13.38
NMISA	–2.30	3.90	–0.90	10.08	28.10	139.05	–3.70	13.19
MIKES	–0.70	3.20	–2.50	9.84	26.50	139.04	–5.30	13.00
AREPA	–0.20	2.20	–3.00	9.56	26.00	139.02	–5.80	12.79
LNE	0.50	4.70	–3.70	10.42	25.30	139.08	–6,50	13.45
PTB	–0.90	1.70	–2.30	9.45	26.70	139.01	–5,10	12.71
BIM	–7.70	16.00	4.50	18.51	33.50	139.92	1.70	20.37

100 kHz			UMTS		BelGIM		INM	
NMI	*Di*	*U(Di)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*
UTE	3.00	20.20	–6.20	22.24	22.80	140.46	–9.00	23.81
INMETRO	–2.00	8.40	–1.20	12.53	27.80	139.25	–4.00	15.14
CENAM	1.30	10.50	–4.50	14.03	24.50	139.40	–7.30	16.40
NML-SIRIM	–0.90	8.40	–2.30	12.53	26.70	139.25	–5.10	15.14
SCL	–3.90	15.20	0.70	17.82	29.70	139.83	–2.10	19.74
A*STAR	–1.80	6.10	–1.40	11.12	27.60	139.13	–4.20	14.00
NPLI	–4.00	6.90	0.80	11.58	29.80	139.17	–2.00	14.37
CMS	–1.20	7.20	–2.00	11.76	27.00	139.19	–4.80	14.51
MSL	2.30	16.50	–5.50	18.94	23.50	139.98	–8.30	20.76
NMIJ	1.30	2.30	–4.50	9.58	24.50	139.02	–7.30	12.81
NIMT	0.10	11.30	–3.30	14.63	25.70	139.46	–6.10	16.92
KRISS	–0.80	4.20	–2.40	10.20	26.60	139.06	–5.20	13.28
VMI-STAMEQ	0.60	16.50	–3.80	18.94	2520	139.98	–6.60	20.76
KIM-LIPI	0.20	21.30	–3.40	23.24	25.60	140.62	–6.20	24.75
NMISA	–1.30	4.70	–1.90	10.42	27.10	139.08	–4.70	13.45
ITDI	0.60	14.20	–3.80	16.97	25.20	139.72	–6.60	18.98
INMETRO	–0.80	7.30	–2.40	11.82	26.60	139.19	–5.20	14.56
UMTS	–3.2	9.3	0.0	0.0	29.0	139.3	–2.8	15.7
BelGIM	25.8	139.0	–29.0	139.3	0.0	0.0	–31.8	139.6
INM	–6.0	12.6	2.8	15.7	31.8	139.6	0.0	0.0

1 MHz			UMTS		INM	
NMI	*Di*	*U(Di)*	*Dij*	*U(Dij)*	*Dij*	*U(Dij)*
NPL	6.00	7.50	–36.60	42.27	13.40	25.91
INRIM	–1.00	11.00	–29.60	43.03	20.40	27.13
VSL	7.00	19.00	–37.60	45.73	12.40	31.24
SP	–9.00	21.00	–21.60	46.60	28.40	32.50
METAS	–5.00	43.00	–25.60	59.83	24.40	49.64
IPQ	–17.00	70.00	–13.60	81.43	36.40	74.26
CEM	–10.00	21.00	–20.60	46.60	29.40	32.50
NRC	–10.00	11.00	–20.60	43.03	29.40	27.13
NIST	8.00	20.00	–38.60	46.16	11.40	31.86
KRISS	–9.00	100.00	–21.60	108.31	28.40	103.03
NPLI	–6.00	21.00	–24.60	46.60	25.40	32.50
INTI	–23.00	25.00	–7.60	48.53	42.40	35.21
JV	–11.00	27.00	–19.60	49.59	30.40	36.66
BEV	–7.00	32.00	–23.60	52.48	26.40	40.49
VNIIM	–18.00	33.00	–12.60	53.10	37.40	41.28
NMIA	–1.00	23.00	–29.60	47.53	20.40	33.82
NMISA	–21.00	33.00	–9.60	53.10	40.40	41.28

1 MHz			UMTS		INM	
NMI	*Di*	*U*(*Di*)	*Dij*	*U*(*Dij*)	*Dij*	*U*(*Dij*)
MIKES	–7.00	31.00	–23.60	51.88	26.40	39.70
AREPA	–22.00	29.00	–8.60	50.71	41.40	38.16
LNE	27.00	42.00	–57.60	59.11	–7.60	48.78
PTB	–14.00	23.00	–16.60	47.53	33.40	33.82
UTE	8.20	62.60	–38.80	75.16	11.20	67.33
INMETRO	33.20	36.70	–63.80	55.47	–13.80	44.29
CENAM	–6.80	42.10	–23.80	59.19	26.20	48.86
NML-SIRIM	15.60	29.90	–46.20	51.23	3.80	38.85
SCL	–8.90	79.10	–21.70	89.37	28.30	82.90
A*STAR	–8.10	34.50	–22.50	54.04	27.50	42.49
NPLI	15.40	29.00	–46.00	50.71	4.00	38.16
CMS	3.10	31.70	–33.70	52.30	16.30	40.25
MSL	2.50	54.90	–33.10	68.88	16.90	60.24
NMIJ	2.80	17.10	–33.40	44.98	16.60	30.12
NIMT	24.80	30.80	–55.40	51.76	–5.40	39.54
KRISS	–8.80	26.60	–21.80	49.38	28.20	36.37
VMI-STAMEQ	–2.10	66.30	–28.50	78.27	21.50	70.79
KIM-LIPI	–4.10	74.10	–26.50	84.98	23.50	78.14
NMISA	–17.10	33.60	–13.50	53.47	36.50	41.76
ITDI	113.90	43.00	–144.50	59.83	–94.50	49.64
INMETRO	–10.00	44.30	–20.60	60.77	29.40	50.77
UMTS	–30.6	41.6	0.0	0.0	50.0	48.4
INM	19.4	24.8	–50.0	48.4	0.0	0.0

Appendix 1

Reported measurement results for NMI participants

VNIIM (Russia)

Comparison date	Relative AC-DC voltage transfer difference δ_{LAB} and expanded uncertainties U_{LAB} (k = 2), $\times 10^{-6}$, at the frequencies					
		20 Hz*	1 kHz	20 kHz	100 kHz	1 MHz
20.05–24.05.2013	δ_{LAB}	2,7	–0,8	–1,5	–5,0	–57
	U_{LAB}	8,3	2,5	2,8	4,0	28,2

UMTS (Ukraine)

Comparison date	Relative AC-DC voltage transfer difference δ_{LAB} and expanded uncertainties U_{LAB} (k = 2), $\times 10^{-6}$, at the frequencies					
		20 Hz*	1 kHz	20 kHz	100 kHz	1 MHz
4.06.2013–18.03.2014	δ_{LAB}	–8	0.3	–1.6	–10	–71
	U_{LAB}	10.4	4.4	4.4	8.4	40

SMS (Azerbaijan)

Comparison date	Relative AC-DC voltage transfer difference δ_{LAB} and expanded uncertainties U_{LAB} (k = 2), $\times 10^{-6}$, at the frequencies					
		20 Hz*	1 kHz	20 kHz	100 kHz	1 MHz
18.06–21.06.2013	δ_{LAB}	22	7,4	12	–25,0	–
	U_{LAB}	18,0	14,2	22,0	25,6	–

BelGIM (Belarus)

Comparison date	Relative AC-DC voltage transfer difference δ_{LAB} and expanded uncertainties U_{LAB} (k = 2), $\times 10^{-6}$, at the frequencies					
		20 Hz*	1 kHz	20 kHz	100 kHz	1 MHz
23.07–24.07.2013	δ_{LAB}	–	4,4	10	19	–
	U_{LAB}	–	24	29	139	–

INM (Romania)

Comparison date		Relative AC-DC voltage transfer difference δ_{LAB} and expanded uncertainties U_{LAB} (k = 2), $\times 10^{-6}$, at the frequencies				
		20 Hz*	1 kHz	20 kHz	100 kHz	1 MHz
06–17.01.2014	δ_{LAB}	3,7	1,5	–3,1	–12,8	–21
	U_{LAB}	3	3	3	12	22

Appendix 2

Reported measurement uncertainty components for NMI-participants

VNIIM (Russia)

Influence quantity	*u*	Standard measurement uncertainty u, $\times10^{-6}$ at the frequency (kHz)				
		0.02	1	20	100	1000
Reference standard	$u(\delta_s)$	**4.0**	**0.9**	**1.0**	**1.7**	**14.0**
Difference measurement	$u(\delta_d)$	**1.14**	**0.86**	**0.99**	**1.06**	**1.66**
Standard deviation of the measurement	$u(\delta_A)$	0.9	0.5	0.7	0.8	1.5
Non-exceptional systematic error of measuring instrument	$u(\delta_B)$	0.7	0.7	0.7	0.7	0.7
Standard measurement uncertainty	$u(\delta_x)$	**4.16**	**1.24**	**1.41**	**2.0**	**14.1**
Expanded uncertainty for confidence level of 95 %	U	**8.3**	**2.5**	**2.8**	**4.0**	**28.2**

Remarks: $u^2(\delta_s) = u^2(\delta_{TH}) + u^2(\delta_{L.G.C}) + u^2(\delta_{skin}) + u^2(\delta_{con})$; $u^2(\delta_d) = u^2(\delta_A) + u^2(\delta_B)$; $u^2(\delta_x) = u^2(\delta_d) + u^2(\delta_s)$.

UMTS (Ukraine)

Influence quantity	*u*	Standard measurement uncertainty u, $\times10^{-6}$ at the frequency (kHz)				
		0.02	1	20	100	1000
Reference standard	$u(\delta_s)$	**5.0**	**2.0**	**2.0**	**4.0**	**19.0**
Difference measurement	$u(\delta_d)$	**1.5**	**0.8**	**0.8**	**1.1**	**6.2**
Standard deviation of the measurement	$u(\delta_A)$	0.5	0.4	0.4	0.5	1.5
Measurement set-up	$u(\delta_C)$	1.4	0.7	0.7	1.0	6.0
Standard measurement uncertainty	$u(\delta_x)$	**5.2**	**2.2**	**2.2**	**4.2**	**20.0**
Expanded uncertainty for confidence level of 95 %	U	**10.4**	**4.4**	**4.4**	**8.4**	**40.0**

Remarks: $u^2(\delta_s) = u^2(\delta_{TH}) + u^2(\delta_{L.G.C}) + u^2(\delta_{skin}) + u^2(\delta_{con})$; $u^2(\delta_d) = u^2(\delta_A) + u^2(\delta_C)$; $u^2(\delta_x) = u^2(\delta_d) + u^2(\delta_s)$.

SMS (Azerbaijan)

Influence quantity	*u*	Standard measurement uncertainty *u*, $\times10^{-6}$ at the frequency (kHz)			
		0.02	1	20	100
Reference standard	$u(\delta_s)$	**8.2**	**6.3**	**10.4**	**12.4**
Difference measurement	$u(\delta_d)$	**3.7**	**3.3**	**3.6**	**3.2**
Standard deviation of the measurement	$u(\delta_A)$	2.1	1.4	2.0	1.1
Measurement set-up	$u(\delta_C)$	3.0	3.0	3.0	3.0
Standard measurement uncertainty	$u(\delta_x)$	**9.0**	**7.1**	**11.0**	**12.8**
Expanded uncertainty for confidence level of 95 %	U	**18.0**	**14.2**	**22.0**	**25.6**

Remarks: $u^2(\delta_s) = u^2(\delta_{TH}) + u^2(\delta_{L.G.C}) + u^2(\delta_{skin}) + u^2(\delta_{con})$; $u^2(\delta_d) = u^2(\delta_A) + u^2(\delta_C)$; $u^2(\delta_x) = u^2(\delta_d) + u^2(\delta_s)$

BelGIM(Belarus)

Influence quantity	*u*	Standard measurement uncertainty *u*, $\times10^{-6}$ at the frequency (kHz)		
		1	20	100
Standard deviation of the measurement	$u(\delta_A)$	3.58	8.37	1.27
AC-DC difference of standard transformer	$u(\delta_E)$	0.5	0.5	1.5
Long instability of standard transformer	$u(\delta_{ins})$	11.55	11.55	69.28
Error of reading	$u^2(\delta_{count})$	0.74	0.74	0.74
Standard measurement uncertainty	$u(\delta_X)$	**12.1**	**14.3**	**69.3**
Expanded uncertainty for confidence level of 95 %	U	**24.2**	**28.6**	**138.6**

Remarks: $u^2(\delta_X)= u^2(\delta_A) + u^2(\delta_E) + u^2(\delta_{ins}) + u^2(\delta_{count})$

INM (Romania)

Influence quantity	*u*	Standard measurement uncertainty u, $\times 10^{-6}$ at the frequency (kHz)				
		0.02	1	20	100	1000
Reference standard	$u(\delta_s)$	**1.0**	**1.0**	**1.0**	**4.0**	**5.0**
Difference measurement	$u(\delta_d)$	**1.1**	**1.1**	**1.1**	**4.5**	**10.0**
Standard deviation of the measurement	$u(\delta_A)$	0.5	0.3	0.4	0.8	1.0
Measurement set-up	$u(\delta_C)$	1.0	1.0	1.0	4.4	10.0
Standard measurement uncertainty	$u(\delta_x)$	**1.5**	**1.5**	**1.5**	**6.0**	**11.0**
Expanded uncertainty for confidence level of 95 %	*U*	**3.0**	**3.0**	**3.0**	**12**	**22.0**

Remarks: $u^2(\delta_s) = u^2(\delta_{TH}) + u^2(\delta_{L.G.C}) + u^2(\delta_{skin}) + u^2(\delta_{con})$; $u^2(\delta_d) = u^2(\delta_A) + u^2(\delta_C)$;$u^2(\delta_x) = u^2(\delta_d) + u^2(\delta_s)$.

Appendix 3

Technical protocol of comparison

Technical protocol
COOMET Key Comparison of AC/DC voltage transfer references
(COOMET.EM-K6a)

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(version 1)

This technical protocol applies to the key comparisons according to the project COOMET566/UA/12, being named as “Comparisons of the national AC/DC voltage transfer references up to 1000V in the frequency range from 10 Hz to 1 MHz”. This comparisons have registered in the BIPM as COOMET.EM-K6.a. The participants of this comparisons are: Ukraine (UMTS), Azerbaijan (SMS), Belarus (BelGIM), Romania (INM), Russia (VNIIM), Slovakia (SMU). Present comparisons have an aim to confirm the equivalence of the compared references and to establish a link between theirs results and the International key comparisons CCEM-K6.a results.

This technical protocol establishes a procedure of the key comparisons COOMET.EM-K6.a and other concomitant actions. The adherence to this technical protocol by national metrology institutes (NMI) is obligatory.

Observance of this obligation will assure the capability to obtain positive measuring results, which will applicable for compare with others results of NMI’s participants.

1 MAGNITUDE OF PHYSICAL QUANTITY IN PRESENT COMPARISONS

The comparisons of the national AC-DC voltage transfer references shall perform at the sinusoidal AC voltage demonstrating such values as:

- the rating root-mean-square voltage: 3 V.

- the required frequency points: 1 kHz, 20 kHz, 100 kHz, 1 MHz, facultative point: 20 Hz.

2 TRAVELING STANDARD

2.1 Concise description and specification

Traveling AC-DC-transfer standard is the Single Junction Thermal Converter type ПНТЭ-6А serial No1848 (thereinafter – the traveling standard ПНТЭ-6А). The traveling standard ПНТЭ-6А have manufactured as three-dimensional construction, in which used the thermocouple type ТВБ-2 (vacuum contact-free thermocouple, design 2). The short specification of the traveling standard ПНТЭ-6А is given bellow:

- input voltage	3 V
- output voltage	5 mV
- input resistance	1000 Ω
- output resistance	20 Ω

The traveling standard ПНТЭ-6А has a square-law response of it’s output thermocouple voltage from the heater current.

The general form of the traveling standard ПНТЭ-6А is shown in Figure 1. The coaxial connector for input voltage of the traveling standard ПНТЭ-6А is completed by detachable adapter in order to provide adaptation to usual connector N-type (female). The output voltage of the traveling standard ПНТЭ-6А is brought to the clip connectors “+” and “–”. The clip connector with marking “⊥” is located nearly and has the electrical link with case of the traveling standard ПНТЭ-6А. The transport suitcase and the traveling standard ПНТЭ-6А are shown in Figure 2.

Figure 1

Figure 2

The complete set of the traveling standard ПНТЭ-6А:

- thermal converter ПНТЭ-6А	1	pcs.
- coaxial adapter	1	pcs.
- technical data sheet	1	copy
- transport suitcase	1	pcs.

The overall dimensions and mass of the traveling standard ПНТЭ-6А:

- diameter of the thermal converter ПНТЭ-6А	50	mm
- length of the thermal converter ПНТЭ-6А	100	mm
- length of the thermal converter ПНТЭ-6А and adapter	153	mm
- overall dimension of the transport suitcase	375×290×84 mm	
- mass of the thermal converter ПНТЭ-6А and adapter	0,44	kg
- total mass with the transport suitcase	2,15	kg

2.2 Rules of handling the traveling standard ПНТЭ-6А

Warning: The thermo-electric transfer of thetraveling standard ПНТЭ-6А shuts out exceeding of input voltage more than on 5%, therefore before his plugging in the proper electric circuits it is necessary to provide defense, for example, automatic blocking which does not allow to set (or to activate) value more then 3,1 V.

The coaxial connector of thetraveling standard ПНТЭ-6А is intended for connecting of voltage 3 V from the source of AC voltage $U_{\sim}$ or from the source of DC voltage $U_{=}$. Terminals with marking of "+", "–" and «⊥» is intended for connecting of measuring device – the high resolution millivoltmeter.

Before performing of the measuring procedure thetraveling standard ПНТЭ-6А must be maintained in active mode (under input voltage 3 V) during 2 h with maintenance of the stable ambient temperature. Thetraveling standard ПНТЭ-6А shall to protect from the streams of ambient air during its functioning.

The traveling standard ПНТЭ-6А shuts out influence of shock and vibration. After completion of measuring and disconnecting from electric circuits it shall be placed in the transport case.

3 BASIC DIRECTIVES FOR PERFORMING THE COMPARISONS

3.1 Definition of the measurement

The relative AC-DC voltage transfer difference δof thetraveling standard ПНТЭ-6А is defined as:

$$\delta = (V_{ac} - V_{dc})/V_{dc},$$

where$V_{ac}$is the RMS value of the AC voltage;

$V_{dc}$is the DC voltage which when reversed produces the same mean output voltage of thetraveling standard ПНТЭ-6А as V_{ac}.

And for compensation of thetraveling standard ПНТЭ-6А asymmetry the value V_{dc} is defined as:

$$V_{dc} = (V_{dc(+)} + V_{dc(-)})/2,$$

where

$V_{dc(+)}$ is the DC voltage of positive polarity (one direction of current), produces output voltage of thetraveling standard ПНТЭ-6А equal to effect of voltage V_{ac};

$V_{dc(-)}$ is the DC voltage of negative polarity (reverse direction of current), produces output voltage of thetraveling standard ПНТЭ-6А equal to effect of voltage V_{ac}.

Note. There are known and widely used the methods of measurement for determination value δ, based on measuring of thermocouple voltage on the output of thermal converter, which is corresponding to values V_{ac} and V_{dc}. Therefore formula $\delta = (V_{ac} - V_{dc})/V_{dc}$ is given to illustrate the definition of value δ; it should neither be relied upon as the only selected methodology, not interpreted as the compulsory procedure.

3.2 Basic procedural guidance

Each participant of comparisons (NMI laboratory) executes on their national (fundamental) AC-DC standard the necessary number of measurements for determination of relative difference δ of thetraveling standard ПНТЭ-6А (thereinafter the value δ, determined by the NMI laboratory, is marked as δ_{LAB}). Determination of the mentioned difference δ_{LAB} shall perform in the frequency points according to item 1. The results of measurement with thetraveling standard ПНТЭ-6А shall be presented for each of this points as:

- the relative AC-DC voltage transfer difference δ_{LAB}, expressed in relative units;

- theexpanded uncertainty U_{LAB} of this measurement shown in similar relative units.

Number of samples in measuring for determination of value δ_{LAB} is set at discretion the NMI laboratory. However, this number must be such, to provide the small enough value$u(\delta_A)$ – the Type A evaluation of standard uncertainty.

Each NMI laboratory that participates in the comparisons shall give the uncertainty budget of the measurements, executed on its national (fundamental) standard. It is recommended to show the uncertainty budget in a due form, in obedience to Annex A, which is inalienable part of this technical protocol. Any NMI laboratory can add any other components of uncertainty in addition to specified in Annex A, which they will consider rational. The uncertainty analysis and calculations shall be performed in accordance with the Guide to the Expression of Uncertainty in Measurement [1, 2]. The expanded uncertainty of the measurements shall be reached by the confidence probability 0,95 and a coverage factor $k = 2$.

4 PARTICIPANTS OF THE COMPARISONS

The NMIs are listed in the chronological order in which they will participate.

Name/Acronym	Full name of NMI and the name of the responsible person	Address Telephone, e-mail
SE "Ukrmetr-teststandard"	State enterprise All-Ukrainian state research and production center for standardization, metrology, certification and consumers' rights protection (SE "Ukrmetrteststandard"), Iurii Darmenko	Metrologichna street 4 Kyiv, 03680, Ukraine ph./fax: +380445263669 ydarmenko@ukrcsm.kiev.ua
VNIIM	All-Russia D.I. Mendeleyev Scientific and Research Institute for Metrology (VNIIM),Vladimir Shevtsov	Moskovsky pr., 19, St. Petersburg, 190005, Russia ph./fax: 007 8123239620 V.I.Shevtsov@vniim.ru
BelGIM	Belarussian State Institute of Metrology (BelGIM), Natalia Petrovskaya	Starovilenskytrakt, 93, Minsk, 220053, Republic of Belarus phone: +375172331510 kazakova@belgim.by
SMU	Slovak Institute of Metrology (SMU), DragosAlexandrescu	street Karloveska 63, Bratislava, 842 55, Slovakia phone: +4212 60294282 fax: +4212 60294912 alexandrescu@smu.gov.sk
INM	National Institute of Metrology (INM), DorinFlamanzeanu	11 Sos. VitanBârzesti, Bucharest, 75669 Romania phone: +40 1 334 55 20 fax: +40 1 334 53 45 dflamanzeanu@inm.ro
SMS	State Metrology Service of the Republic of Azerbaijan, MaarifZeynalov	MardanovGardashlary str.124 Baku, AZ 1147, Azerbaijan phone: +994124499959 maarif61@gmail.com

5 ORDER OF COMPARISONS

5.1 Design chart of comparisons

NMI Laboratory	Term of comparison	Term of report
SE “Ukrmetrteststandard”,Ukraine	April 2013	–
VNIIM, Russia	May 2013	June 2013
BelGIM, Republic of Belarus	June 2013	July 2013
SMU, Slovakia	July 2013	August 2013
INM, Romania	August 2013	September 2013
SMS, Azerbaijan	September 2013	October 2013
SE “Ukrmetrteststandard”,Ukraine	October 2013	November 2013

5.2 The scheme of addressing

SE “Ukrmetrteststandard” is responsible for delivery of thetraveling standard ПНТЭ-6А to address of VNIIM (St. Petersburg) and after completion of measurement is responsible for delivery to address of BelGIM (Minsk).

Bel. SIM is responsible for returning of thetraveling standard ПНТЭ-6А in the pilot laboratory to address of SE “Ukrmetrteststandard” (Kyiv).

SE “Ukrmetrteststandard” is responsible for dispatch of thetraveling standard ПНТЭ-6Аto address of SMU (Bratislava).

SMU is accountable for the dispatch of thetraveling standard ПНТЭ-6А to address of INM (Bucharest).

INM is responsible for returning of thetraveling standard ПНТЭ-6А in the pilot laboratory to address of SE “Ukrmetrteststandard” (Kyiv).

SE “Ukrmetrteststandard” is responsible for delivery of thetraveling standard ПНТЭ-6А to address of NMC (Baku).

NMC is responsible for returning of thetraveling standard ПНТЭ-6А in the pilot laboratory to address of SE “Ukrmetrteststandard” (Kyiv).

The NMI laboratories are responsible for dispatch of thetraveling standard ПНТЭ-6А in a next laboratory in accordance with the chart of addressing. At the dispatch of thetraveling standard ПНТЭ-6А every participating laboratory must advise a next participant and the pilot laboratory about it. A report is sent by an e-mail in the filled form according to Figure 3. If it is necessary, they report also about the details of transporting.

Mark about a dispatch	
Date of dispatch	
NMI (National Metrology Institute)	
Name of responsible person	
Information about a dispatch	
Notes:	

Figure 3

After the receipt of thetraveling standard ПНТЭ-6А a participating laboratory must without delay check up its good condition and advise the pilot laboratory about it. It is necessary to send a report by an e-mail in the filled form according to Figure 4.

Mark about arrival		
Date of arrival		
NMI (National Metrology Institute)		
Name of responsible person		
Transported standard	□ Damaged	□ Not damaged
Notes:		

Figure 4

Each participating NMI laboratory compensates the expenses for measurements, transportation and any customs fees, and also assumes responsibility for any damage which can happen within borders of the country.

For transportation it is recommended to apply ATA Carnet. A person, who organizes the transportation, must provide that at every moving of thetraveling standard ПНТЭ-6А the document of “Carnet” was presented on a custom in the country of sending and after its arrival in the country of setting. Document of “Carnet” it is necessary to dispatch together with other accompanying documents in order that a handling transport agent could get a release from custom duty.

Warning: Be aware that it is not allowed to pack the “Carnet” together with thetraveling standard ПНТЭ-6А in its transport suitcase. On occasion it is possible to fasten the “Carnet” on packing.

In case of organizational delay, the pilot laboratory informs the participants and, if it is necessary, makes change in the chart of comparisons.

6 RESULTS OF COMPARISONS

The NMI laboratories shall present the results of comparisons to the pilot laboratory as quickly as possible, but not later than four weeks after completion of measurements. It is necessary to send the report with the results of measurements in a due form stated in AnnexB which is inalienable part of this technical protocol. It is possible to send additional information which the NMI laboratory supposes necessary.

If the pilot laboratory after study of total set of measurement results finds out a result which seems anomalous, the pilot laboratory proposes for appropriate NMI laboratory to check up their result in the presence of errors of calculation, but does not report at that about a value and sign of seeming anomaly. If an error is not found out, a result is accepted as final.

The pilot laboratory after completion of comparisons produces the Draft A of report which is sent as quickly as possible to all participants for comments with a reasonable last date for answers. A date of sending of the Draft A to the participants is considered as final date of comparisons. The Draft A is confidential for participants. Copies are not given for any other sides who are not the participant, and any graphs or other information of Draft A not utilize in verbal presentations at some external conference without the special consent of all of participants.

After reception of participant comments the pilot laboratory prepares the Draft B version of the report, including appendix, which iscontaining suggestions about reference value and degree of equivalence. At calculation of the reference value of key comparison the pilot laboratory shall utilize a method which after agreement with the participants, and similarly with the COOMET Working Group for key comparisons and the Consultative Committee will consider as the most suitable. The pilot laboratory submits the Draft B to the COOMET Working Group for key comparisons.

The NMI laboratory, which considers its results are unrepresentative for its national reference, can request subsequent bilateral comparison with the pilot laboratory or with one of participants. It must be done in maximally short term after completion of these comparisons. The subsequent bilateral comparisons will be considered as new and separate.

REFERENCES

[1] Guide to Expression of Uncertainty in Measurement, first edition published in 1993 by BIPM/IEC/FCC/ISO/IUPAP/OIML.

[2] РМГ 43-2001. ГСИ. Применение «Руководства по выражению неопределённости измерений». – Минск: МГС по стандартизации, метрологии и сертификации, 2002