SIM Regional Comparison of AC-DC VOLTAGE TRANSFER DIFFERENCE

SIM.EM-K6a, SIM.EM-K9, SIM.EM-K11 and SIM.EM-Supplementary 120 V / 53 Hz

FINAL REPORT

January 2004 – December 2004

CONTENTS

1. Introduction

In the Sistema Interamericano de Metrología (SIM) there are several National Metrology Institutes (NMIs) having calibration and measurement capabilities in the ac-dc voltage transfer difference, but only three NMIs have participated in the CCEM Key Comparisons of ac-dc transfer difference, CCEM-K6a, CCEM-K9 and CCEM-K11.

Three comparisons, SIM.EM-K6a, SIM.EM-K9, SIM.EM-K11, were proposed to assess the measurement capabilities of the remaining NMIs in the SIM region, in ac-dc voltage transfer difference. The proposed test points were selected to link the results of such comparisons with the equivalent CCEM Key Comparisons, through the three NMIs participating in both.

Additionally, a fourth comparison, SIM.EM-Supplementary, was proposed, in support of the SIM NMIs power/energy meter calibration capabilities.

CENAM volunteered to provide the travelling standard (TS) and to pilot and coordinate the comparison. It was agreed that the comparison references values were to be based on the results provided by the laboratories with participation in the key comparisons.

The comparisons started in January 2004 and the measurements were concluded in December 2004. The Draft A was issued by the pilot laboratory and was reviewed by the participants in 2006, comments were added and the final results are reported in this document.

2. Definition of the measurand

The measured quantity is the ac-dc voltage transfer difference of the travelling standard:

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

where:

δ is the ac-dc voltage transfer difference of the travelling standard
V_{ac} is the rms value of the ac input voltage
V_{dc} is the dc input voltage which when reversed produces the same mean output voltage of the transfer standard as V_{ac}.

The measurement points for the different comparisons are shown in Table I.

Table I. Test points

SIM.EM-K6a	SIM.EM-K9	SIM.EM-K11	SIM.EM-Supplementary
3 V / 1 kHz 3 V / 20 kHz 3 V / 100 kHz 3 V / 1 MHz	1 kV / 1 kHz 1 kV / 10 kHz 1 kV / 20 kHz 1 kV / 50 kHz 1 kV / 100 kHz	100 mV / 1 kHz 100 mV / 20 kHz 100 mV / 100 kHz 100 mV / 1 MHz	120 V / 53 Hz

3. Travelling standard description

The travelling standard was an ac-dc thermal transfer standard, model Fluke 792A, fitted with accessories for voltage measurements.

Description: **AC-DC Transfer Standard Fluke** (with a type-Nm/type-Nf adapter attached)
Model: 792A
Serial Number: 5685005

Accessories:

Description: **1000 V Range Resistor, Fluke**
Model: 792 A-7002
Serial Number: 5685005

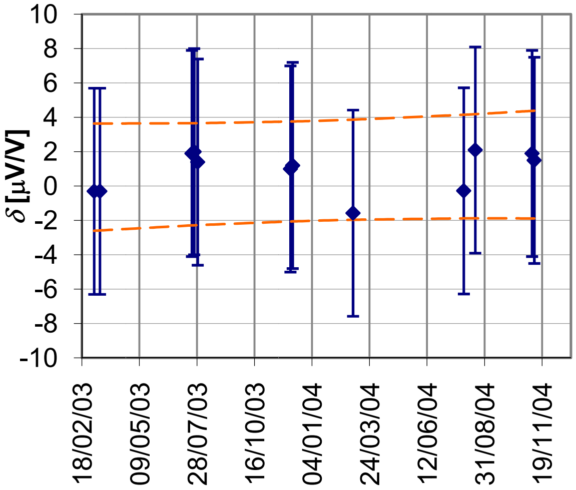
Description: **Power Pack, Fluke**
Model: 792 A-7001
Serial Number: 5370005

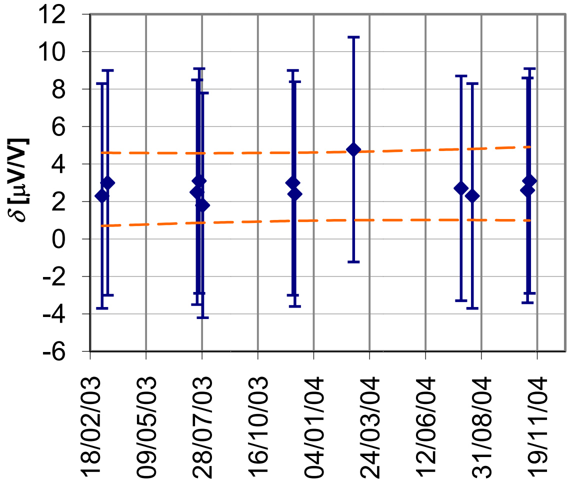
Description: **Power Pack Cable, Fluke**
Model: 792 A
Serial Number: N/A

Description: **Handbook Fluke 792A**
Model: N/A
Serial Number: N/A

The travelling standard belongs to the pilot laboratory, CENAM, who has maintained calibration of this device since 1995. The stability observed is within the manufacturer´s specification and within the uncertainty obtained by the pilot laboratory.

The following graphs show the measurements that the pilot laboratory made before the departure of the travelling standard in 2003 and during the comparison in 2004. The graphics show that the stability evaluated [2], shown in dashed lines, is good enough to serve as a travelling standard.


3 V / 1 kHz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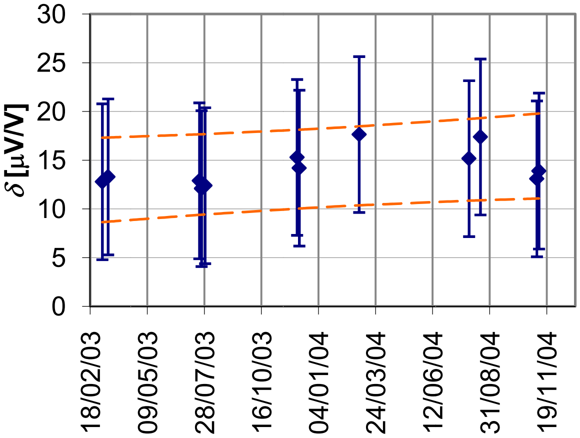
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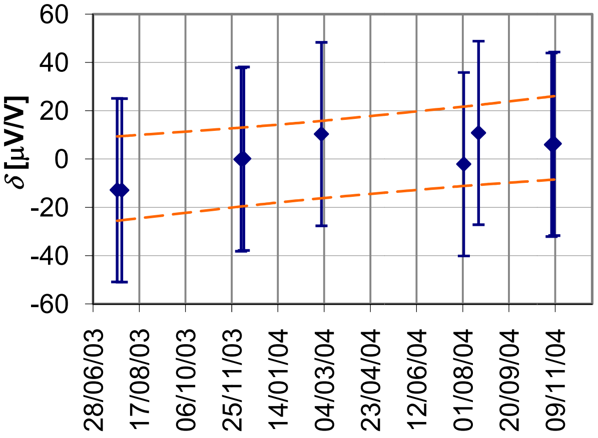
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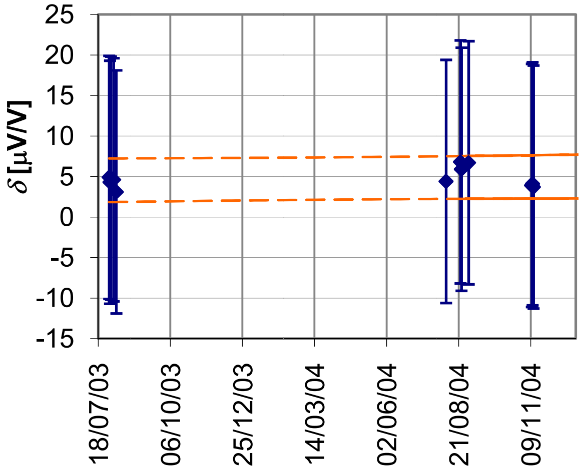
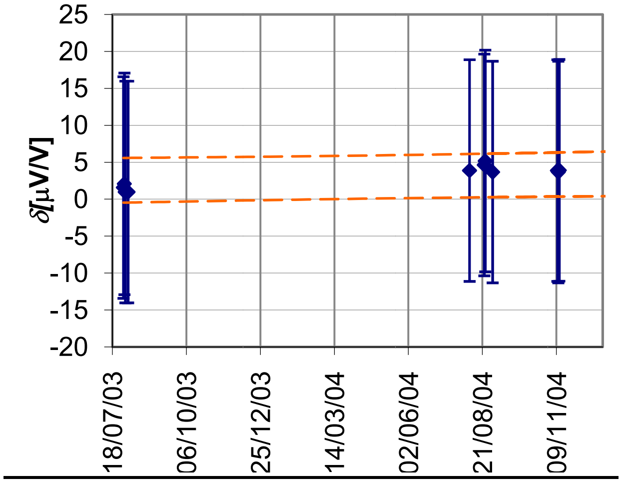

1 kV / 1 kHz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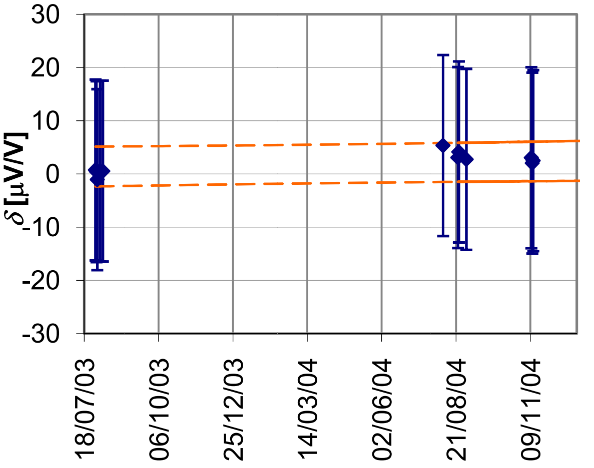
1 kV /20 kHz



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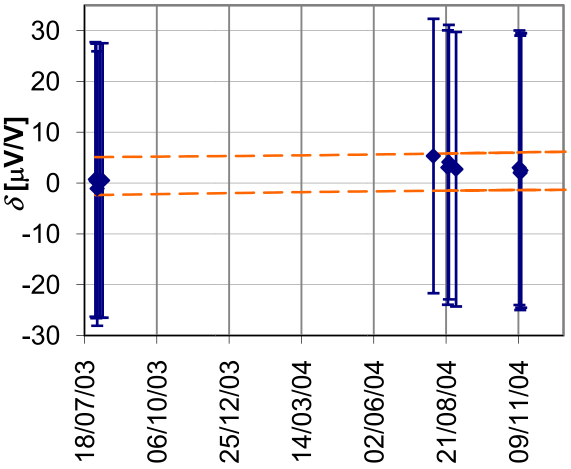
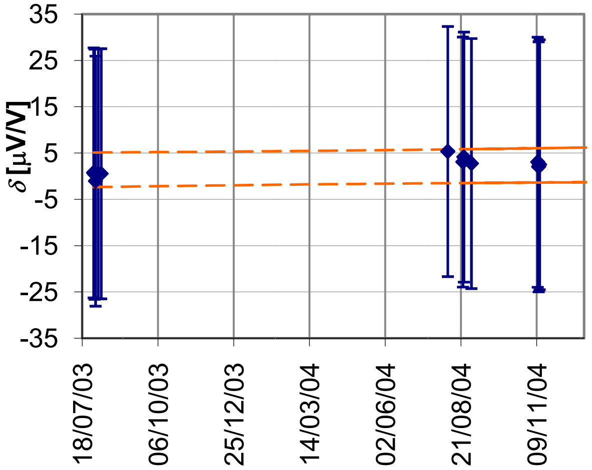
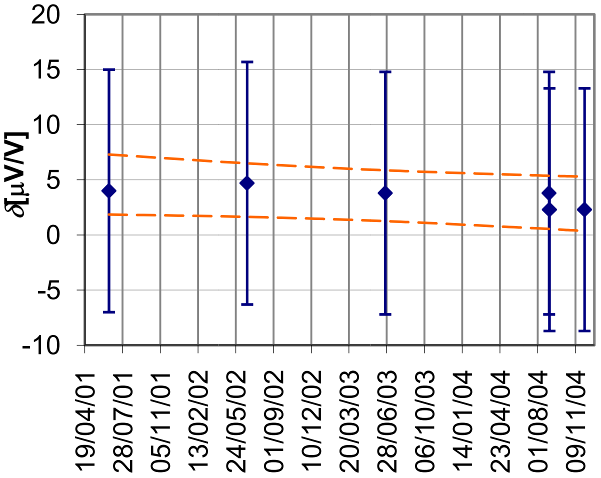


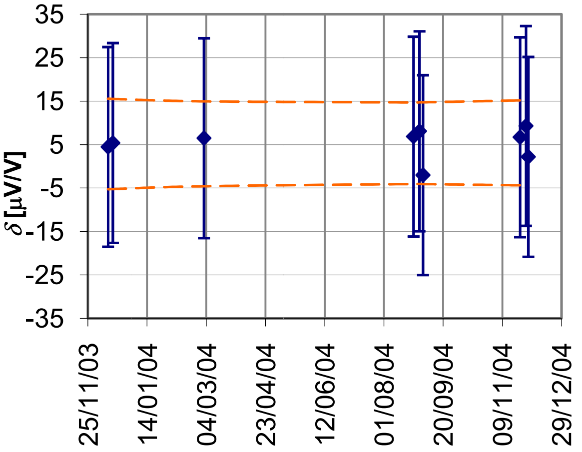
1 kV / 100 kHz



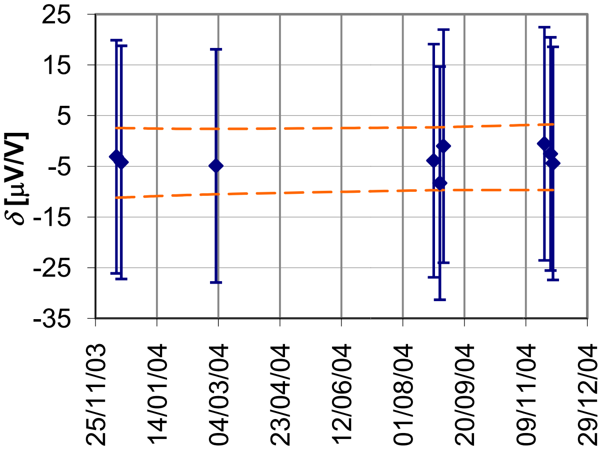
120 V / 53 Hz

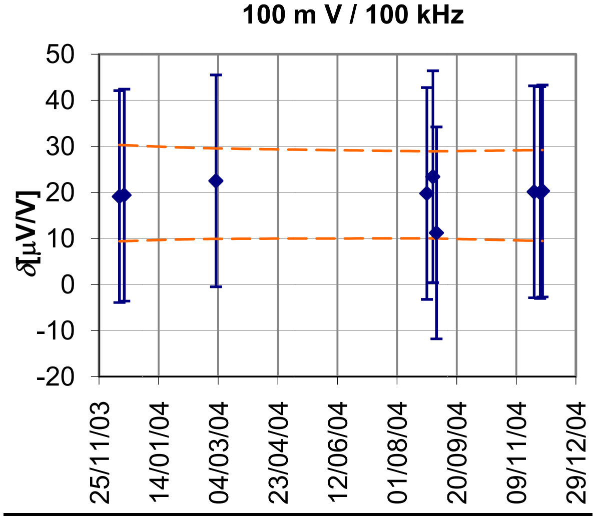


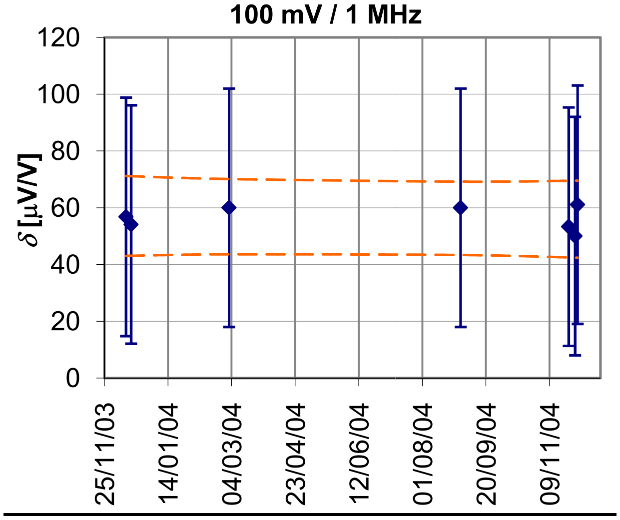
100 mV / 1 kHz



100 mV / 20 kHz







4. Participants

NRC	National Research Council, Canada Contact: Peter Filipski, Peter.Filipski@nrc-cnrc.gc.ca
NIST	National Institute of Standard and Technology, USA Contact: Thomas Lipe, Thomas.lipe@nist.gov Joseph Kinard, Joseph.Kinard@nist.gov
INMETRO	Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial, Brazil. Contact: Giovanna Borghi, gbalmeida@inmetro.gov.br Edson Afonso, eafonso@inmetro.gov.br
INTI	Instituto Nacional de Tecnología Industrial, Argentina Contact: Lucas Di Lillo, ldili@inti.gov.ar Héctor Laiz , laiz@inti.gov.ar
UTE	Administración Nacional de Usinas y Transmisiones Eléctricas, Uruguay Contact: Alfredo Spaggiari, aspaggiari@ute.com.uy Daniel Slomovitz, d.slomovitz@ieee.org
CENAM	Centro Nacional de Metrología, México (Pilot Laboratory) Contact: Sara Campos, scampos@cenam.mx

5. Circulation of the travelling standard

A measurement period of six weeks for each participant was agreed upon. This period included time for clearing the customs, receiving, preparation, making measurements and shipping to the next laboratory.

Each laboratory, except CENAM, measured the travelling standard once. The travelling standard returned to CENAM after measurement at NIST, NRC and the South American NMIs. It was agreed upon to hand-carry the travelling standard when sent to South America, to avoid any possible damage and delays during the customs clearance. Flight tickets Mexico-Argentina-Mexico, Uruguay-Brazil-Uruguay and Brazil-Mexico-Argentina were financed by the grant from the Organization of the American States.

The pilot laboratory sent the travelling standard to the first participating laboratory in January 2004. The whole comparison was carried out without an undue delay during the 2004. After the measurements in the five laboratories, the travelling standard returned to the pilot laboratory in November 2004. The pilot laboratory performed the last measurements in December 2004. The schedule followed by the travelling standard is shown on Table II.

Table II. Schedule followed by the travelling standard.

Participant Laboratory	Date of measurements	Transport of the travelling standard
CENAM (Mexico)	December 2003	
NIST (United States)	January and February 2004	Courier Service
CENAM (Mexico)	February 27th 2004	Courier Service
INTI (Argentina)	4th March To 16th April 2004	Hand Carried
UTE (Uruguay)	18th May to 22nd June 2004	Hand Carried
INMETRO (Brazil)	June 25th 2004	Hand Carried
CENAM (Mexico)	August 2004	Hand Carried
NRC (Canada)	September to October 2004	Courier Service
CENAM (México)	November 2004	Courier Service

In order to conduct the comparison in a timely fashion, it was helpful that the participant laboratories knew the customs procedures for their port of entry to get the importation permission prior to the arrival of the travelling standard, as each country had different procedures and different periods of answer.

During the circulation of the travelling standard there was a constant contact between the sending laboratory, the receiving laboratory and the pilot laboratory, to communicate the departure and arrival dates of the travelling standard.

6. Measurement methods

The participants were requested to submit a detailed report of their measurements, which are attached as an Appendix A of this document. The following information was extracted from the reports.

All participants used a two channel method. Three participants used a nanovoltmeter to read the output voltage of their standards and an 8 ½ digits multimeter to read the output voltage of the travelling standard. Two participants used nanovoltmeters to read both the output of their standard and the output of the travelling standard. Five participants used two sources with an external relay to apply the AC and the DC voltage to the instrument under test. Two participants indicated the AC-DC sequence used to minimize the thermal drift; NRC reported using the sequence AC, DC^+, DC^-, AC, except for the 1 kV measurement points, in which case NRC applied the sequence AC,DC^+,AC,DC^-,AC. CENAM used the sequence AC,DC^+,AC,DC^-,AC exclusively.

For frequencies below 1 MHz, NIST used as plane of reference the center of a type-GR874 Tee connector, the travelling standard being connected to it by a type-GR874 –to –type-N adapter. At 1 MHz NIST used as a plane of reference the center of a type-N tee connector. INTI, UTE, INMETRO and CENAM used as plane of reference the center of a type-N Tee connector and NRC used the center of a special asymmetrical tee, having as one arm a type-GR874 connector and as the other arm a type-N connector.

To calibrate the travelling standard the participating laboratories used the standards shown in Table III a, their sources of traceability are shown in Table III b.

Only four laboratories participated in all comparisons. NIST participated in SIM.EM-K6a and SIM.EM-K9. INTI decided to withdraw their results from the comparison SIM.EM-K6a, after discovering a systematic error. See section 12 for corrective actions.

Table III.a Standards used for measuring the travelling standard

Laboratory	Standard used for measuring the travelling standard			
	SIM.EM-K6a	**SIM.EM-K9**	**SIM.EM-K11**	**SIM.EM-Supplementary**
NIST	SJTC	SJTC + RR		
INTI		PMJTC + 100 kΩ RR PMJTC + 200 kΩ RR	PMJTC - 10:1 RVD Micropotentiometer Ballantine	PMJTC + RR
UTE	1 V SJTC + RR	1 V SJTC + RR	1 V SJTC - 10:1 RVD	1 V SJTC + RR
INMETRO	TTS Fluke 792A	TTS Fluke 792A	TTS Fluke 792A	TTS Fluke 792A
CENAM	1 V PMJTC + 400 Ω RR	1,5 V PMJTC + 124 kΩ RR	TTS Fluke 792A – micropotentiometer H12	1 V PMJTC + 30 kΩ RR
NRC	MJTC + 400 Ω RR	1 V PMJTC +200 kΩ RR	205 Ω SJTC	MJTC+ 6 kΩ RR

SJTC: Single Junction Thermal Converter
PMJTC: Planar Multijunction Thermal Converter
TTS: Thermal Transfer Standard
RVD: Resistive Voltage Divider
RR: Range Resistor

Table III. b Sources of traceability

Laboratory	SIM.EM-K6a	SIM.EM-K9	SIM.EM-K11	SIM.EM-Supplementary
NIST	Own realization			
INTI		PTB at 3 V Step up in voltage procedure	PTB at 1 V Step down in voltage procedure	PTB at 3 V Step up in voltage procedure
UTE	PTB at 3 V	PTB at 100 V Step up in voltage procedure	PTB at 3 V Step down in voltage procedure	PTB at 100 V Step up in voltage procedure
INMETRO	PTB at 3 V	PTB at 1 kV	PTB at 100 mV	PTB at 120 V
CENAM	PTB at 1 V Step up in voltage procedure	PTB at 1 V Step up in voltage procedure	PTB at 1 V Step down in voltage procedure	PTB at 1 V Step up in voltage procedure
NRC	Own realization			

NRC and NIST have their own calculable standards to provide traceability to the working standards used during the comparison. INTI, UTE, INMETRO and CENAM used standards whose values are traceable to the Physikalisch Technische Bundesanstalt (PTB) standards. INMETRO standards were directly calibrated by the PTB at the comparison test points. INTI, UTE and CENAM performed voltage step up and step down procedures to derive the values of their working standards at 3 V, 1 kV and 100 mV.

The reports show that in all laboratories the environmental conditions during the calibration of the travelling standard were at (23 ± 1) °C and (45 ± 15) % of R.H.

7. Environmental conditions during transportation

A temperature, humidity and pressure data logger traveled with the travelling standard to monitor the ambient conditions during the transport. There was no evidence that the environmental condition changes had an effect on the stability of the TS and thus influenced the final measurements.

8. Measurement results

This section summarizes the results reported by the participants. They reported the expanded uncertainty with a coverage factor of k =2, except for UTE who reported their results with a coverage factor of k=1. In sections 9 and 10 the expanded uncertainty is evaluated, taking into account the degrees of freedom reported by the participants, at a confidence level of 95,45 %.

8.1 SIM.EM-K6a. results

Table IV. Results at 3 V, ac-dc voltage transfer difference δ_i and its uncertainty $U_{\delta i}$.

Laboratory i	Calibration date	SIM.EM-K6a 3 V				
		δ_i and $U_{\delta i}$ (k=2,0) µV/V				
			1 kHz	20 kHz	100 kHz	1 MHz
NIST	Jan to Feb, 2004	δ_i	0.0	2.0	16.0	1.0
		$U_{\delta i}$	3.2	3.2	8.5	17.2
UTE	18th May to 22nd June, 2004	δ_i	3.0	6.0	18.0	3.0
		$u_{\delta i}$	5.5	5.4	9.5	30
INMETRO	28th June to 28th July, 2004	δ_i	1.0	4.0	13.0	-22.0
		$U_{\delta i}$	4	4	5	32
CENAM	3rd to 20th August, 2004	δ_i	0.9	2.5	16.3	4.4
		$U_{\delta i}$	6	6	8	38
NRC	Sept to Oct, 2004	δ_i	0.3	2.5	16.5	10
		$U_{\delta i}$	1.2	2.8	7.2	17

8.2 SIM.EM-K9 results

Table V. Results at 1 kV, ac-dc voltage transfer difference δ_i and its uncertainty $U_{\delta i}$.

Laboratory i	Calibration date	SIM.EM-K9 1 kV					
		δ_i and $U_{\delta i}$ (k=2,0) µV/ V					
			1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
NIST	Jan to Feb 2004	δ_i	10	4	1	-18	-35
		$U_{\delta i}$	11.6	11.7	14.1	15.4	23.4
INTI	4th March to 16th April 2004	δ_i	5.2	3.2	6.1	-1.7	10.5
		$U_{\delta i}$	16	20	33	37	74
UTE	18th May to 22nd June 2004	δ_i	4	10	11		
		$u_{\delta i}$	11	12	11		
INMETRO	28th June to 28th July 2004	δ_i	5	0	-2	-9	-25
		$U_{\delta i}$	18	18	18	18	42
CENAM	7th to 24th August 2004	δ_i	5.7	4.2	3.9	3.3	3.9
		$U_{\delta i}$	15	15	17	27	27
NRC	Sept to Oct 2004	δ_i	6.7	2.9	-2.2	-10.6	-18
		$U_{\delta i}$	10	10	10	13	25

8.3 SIM.EM-K11 results

Table VI. Results at 100 mV, ac-dc voltage transfer difference δ_i and its uncertainty $U_{\delta i}$.

Laboratory i	Calibration date	SIM.EM-K11 100 mV				
		δ_i and $U_{\delta i}$ (k=2,0) µV/ V				
			1 kHz	20 kHz	100 kHz	1 MHz
INTI	4th March to 16th April 2004	δ_i	8.7	3.0	19.0	14.0
		$U_{\delta i}$	12.6	13	25	75
UTE	18th May to 22nd June 2004	δ_i	14.0	-2.0	18.0	26
		$u_{\delta i}$	7.5	7.7	18	52
INMETRO	28th June to 28th July 2004	δ_i	8.0	-2.0	18.0	79.0
		$U_{\delta i}$	8.0	8.0	13.0	98.0
CENAM	26th to 30th August 2004	δ_i	7.5	-6.0	21.6	59.9
		$U_{\delta i}$	23	23	23	42
NRC	Sept to Oct 2004	δ_i	9.5	-1.8	24.1	75.0
		$U_{\delta i}$	9.5	8.5	10.3	23.0

8.4 SIM.EM-Supplementary point at 120 V / 53 Hz

Table VII. Results at 120 V, ac-dc voltage transfer difference δ_i and its uncertainty $U_{\delta i}$,

Laboratory i	Calibration date	SIM.EM-Supplementary 120 V	
		δ and U_{δ}(k=2,0) µV/ V	
			53 Hz
INTI	4th March to 16th April 2004	δ_i	2.2
		$U_{\delta i}$	12
UTE	18th May to 22nd June 2004	δ_i	2.0
		$u_{\delta i}$	7.0
INMETRO	28th June to 28th July 2004	δ_i	3.0
		$U_{\delta i}$	14
CENAM	7th to 24th August 2004	δ_i	2.3
		$U_{\delta i}$	11
NRC	Sept to Oct 2004	δ_i	4.3
		$U_{\delta i}$	2.7

9. Reference value

The reference value, δ_{SIM}, was calculated as the weighted mean [3] of the reported values from the laboratories that took part in the corresponding CCEM key comparison; these are NIST, NRC and INTI.

$$\delta_{SIM} = \frac{\sum_{i=1}^{n} w_i \, \delta_i}{\sum_{i=1}^{n} w_i} \quad \text{with} \quad w_i = \frac{1}{u_{\delta_i}^2} \tag{1}$$

where: u_{δ_i} is the standard uncertainty associated with the reported δ_i values.

The standard uncertainty of the reference values, $u_{\delta_{SIM}}$, was evaluated as [3][4] :

$$u_{\delta_{SIM}} = \frac{1}{\sqrt{\sum_{i=1}^{n} w_i}} \tag{2}$$

The measurement results of NRC, NIST and INTI were considered independent; since NRC and NIST have their own calculable standards and INTI has traceability to the values of the uncorrelated PTB standards.

The expanded uncertainty of the reference value was evaluated as:

$$U_{\delta_{SIM}} = k u_{\delta_{SIM}} \tag{3}$$

where k was estimated at a confidence level of 95,45 % taking into account the reported effective degrees of freedom as:

$$\upsilon_{eff} = \frac{u^4_{\delta_{SIM}}}{\sum_{i=1}^{n} \frac{\left(\frac{w_i}{\sum_{i=1}^{n} w_i} u_{\delta_i} \right)^4}{\upsilon_{\delta_i}}} \tag{4}$$

where ν_{eff} are the effective degrees of freedom of the δ_{SIM} and υ_{δ_i} are the effective degrees of freedom associated with the δ_i.

10. Degree of equivalence

The degree of equivalence (D_i) between the i-th participant with respect to the reference value (δ_{SIM}) was evaluated as follows:

$$D_i = \delta_i - \delta_{SIM} \qquad (5)$$

For the laboratories without contribution to the reference value, the expanded uncertainty of D_i (U_{D_i}) was estimated as[4]:

$$U_{D_i} = k_{Di}\sqrt{u^2_{\delta_i} + u^2_{\delta_{SIM}}} \qquad (6)$$

For the laboratories with contribution to the reference value, the expanded uncertainty of D_i (U_{D_i}) was estimated as[4]:

$$U_{D_i} = k_{Di}\sqrt{u^2_{\delta_i} - u^2_{\delta_{SIM}}} \qquad (7)$$

where $k_{Di,}$ for laboratories without contribution to the reference value, was estimated at a confidence level of 95,45 %, taking into account the effective degrees calculated as,

$$\upsilon_{eff} = \frac{u^4{}_{D_i}}{\dfrac{u^4{}_{\delta_i}}{\upsilon_{\delta_i}} + \dfrac{u^4{}_{\delta_{SIM}}}{\upsilon_{eff\,\delta_{SIM}}}} \qquad (8)$$

For laboratories that contributed to the reference value, the effective degrees of freedom were calculated as:

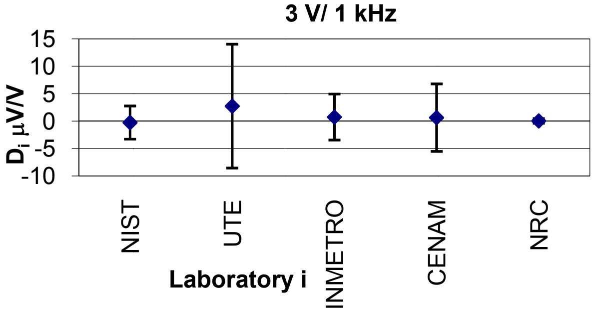
$$\upsilon_{eff} = \frac{u^4{}_{D_i}}{\dfrac{\left[u_{\delta_i} * \left(1 - \dfrac{w_i}{\sum_{i=1}^{n} w_i}\right)\right]^4}{\upsilon_{\delta_i}} + \sum_{i=i+1}^{n} \dfrac{\left[u_{\delta_i} * \dfrac{w_i}{\sum_{i=1}^{n} w_i}\right]^4}{\upsilon_{\delta_i}}} \qquad (9)$$

10.1 Degree of equivalence SIM.EM-K6a

At 3 V, the reference values were evaluated as the weighted mean of the values from NRC and NIST. Correlations between the results were not considered because the laboratories that did not contribute to the reference value, had neither traceability to the values of NRC nor to the values of NIST.

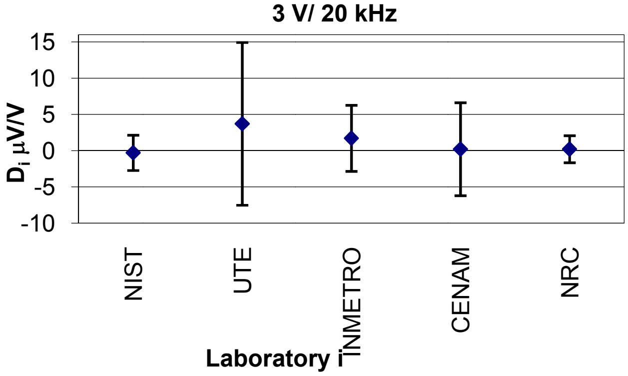
Degree of equivalence D_i and its uncertainty U_{D_i} at 3 V / 1 kHz, in µV/V; for k=2.0

3 V / 1 kHz				
$\delta_{SIM.EM\text{-}K6a}$= 0.3 µV/V ; $U_{\delta_{SIM.EM\text{-}K6a}}$ =1.2 µV/V				
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{D_i}
NIST	0.0	3.2	-0.3	3.0
UTE	3.0	5.5	2.7	11.3
INMETRO	1.0	4.0	0.7	4.2
CENAM	0.9	6.0	0.6	6.2
NRC	0.3	1.2	0.0	0.4



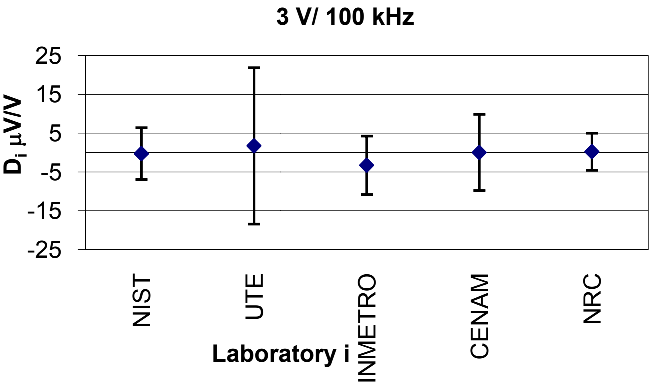
Degree of equivalence D_i and its uncertainty U_{D_i} at 3 V / 20 kHz, in µV/V; for k=2.0

3 V / 20 kHz				
$\delta_{SIM.EM\text{-}K6a}$ = 2.3 µV/V ; $U_{\delta_{SIM.EM\text{-}K6a}}$ = 2.1 µV/V				
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{D_i}
NIST	2.0	3.2	-0.3	2.4
UTE	6.0	5.4	3.7	11.2
INMETRO	4.0	4.0	1.7	4.6
CENAM	2.5	6.0	0.2	6.4
NRC	2.5	2.8	0.2	1.9



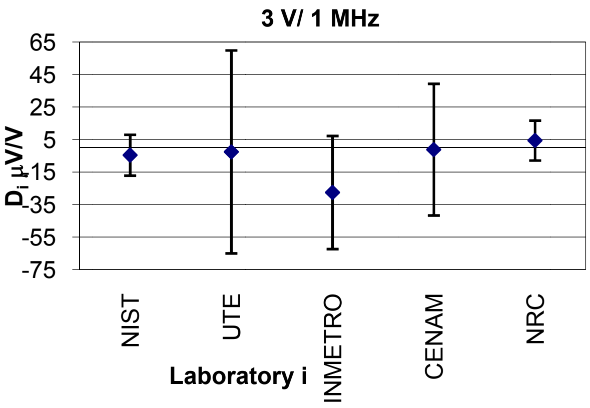
Degree of equivalence D_i and its uncertainty U_{D_i} at 3 V / 100 kHz, in µV/V.

3 V / 100 kHz					
$\delta_{SIM.EM\text{-}K6a}$ = 16.3 µV/V ; $U_{\delta_{SIM.EM\text{-}K6a}}$ = 5.8 µV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}	k
NIST	16.0	8.5	-0.3	6.7	2.1
UTE	18.0	9.5	1.7	20.1	2.0
INMETRO	13.0	5.0	-3.3	7.5	2.0
CENAM	16.3	8.0	0.0	9.8	2.0
NRC	16.5	7.2	0.2	4.8	2.1



Degree of equivalence D_i and its uncertainty U_{D_i} at 3 V / 1 MHz, in μV/V.

3 V / 1 MHz					
$\delta_{SIM.EM-K6a}$ = 5.6 μV/V ; $U_{\delta_{SIM.EM-K6a}}$ = 12.4 μV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{D_i}	k
NIST	1.0	17.2	-4.6	12.6	2.1
UTE	3.0	30.0	-2.6	62.4	2.0
INMETRO	-22.0	32.0	-27.6	34.8	2.0
CENAM	4.4	38.0	-1.2	40.5	2.0
NRC	10.0	17.0	4.4	12.3	2.1



The results at 3 V show a degree of equivalence lower than 3 μV/V at 1 kHz, 4 μV/V at 20 kHz, 4 μV/V at 100 kHz, and 5 μV/V at 1 MHz, except for one laboratory at 1 MHz. All the differences between the reported values and the reference value are within the uncertainty reported by the participants.

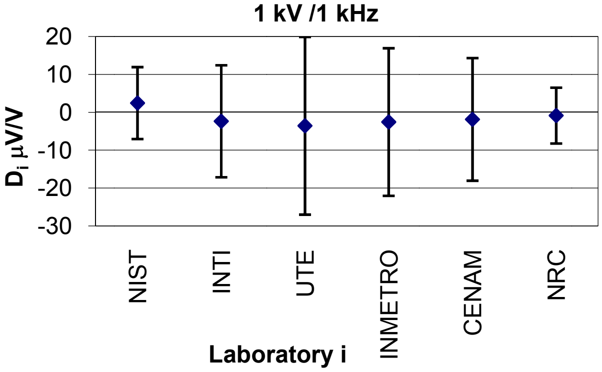
10.2 Degree of equivalence SIM.EM-K9

For the points at 1 kV, the reference values were evaluated as the weighted mean of values from NRC, NIST and INTI. As mentioned in the point 6 of this document, the values of UTE, INTI and CENAM have traceability to the PTB standards at 100 V, 3 V and 1 V, whereas INMETRO have traceable values to PTB standards at 1 kV.

Correlation between UTE, INMETRO and CENAM may exist with respect to INTI values, at 1 V and 3 V levels, since they are traceable to PTB standards. It should be considered, that the voltage step up procedures that these NMIs conducted in order to scale from 1 V or 3 V up to 1 kV, ensures that the effects of the correlation between the laboratories at 1 V and 3 V can be considered negligible at 1 kV.

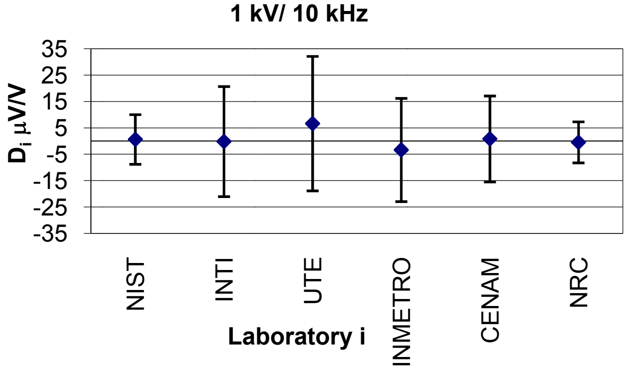
Degree of equivalence D_i and its uncertainty U_{D_i} at 1 kV /1 kHz, in μV/V; for k=2.0

1 kV / 1 kHz				
$\delta_{SIM.EM-K9}$= 7.6 μV/V ; $U_{\delta_{SIM.EM-K9}}$ = 6.9 μV/V				
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}
NIST	10.0	11.6	2.4	9.5
INTI	5.2	16.0	-2.4	14.8
UTE	4.0	11.0	-3.6	23.5
INMETRO	5.0	18.0	-2.6	19.5
CENAM	5.7	15.0	-1.9	16.2
NRC	6.7	10.0	-0.9	7.4



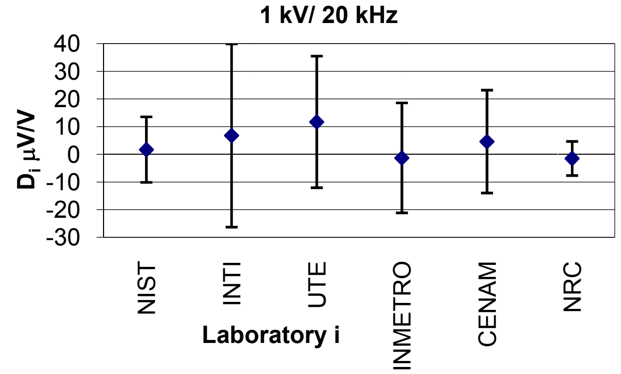
Degree of equivalence D_i and its uncertainty U_{D_i} at 1 kV /10 kHz, in μV/V.

1 kV / 10 kHz					
$\delta_{SIM.EM\text{-}K9}$= 3.3 μV/V ; $U_{\delta_{SIM.EM\text{-}K9}}$ = 7.2 μV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}	k
NIST	4.0	11.7	0.7	9.4	2.0
INTI	3.2	20.0	-0.1	20.9	2.2
UTE	10.0	12.0	6.7	25.5	2.0
INMETRO	0.0	18.0	-3.3	19.6	2.0
CENAM	4.2	15.0	0.9	16.3	2.0
NRC	2.9	10.0	-0.4	7.8	2.2



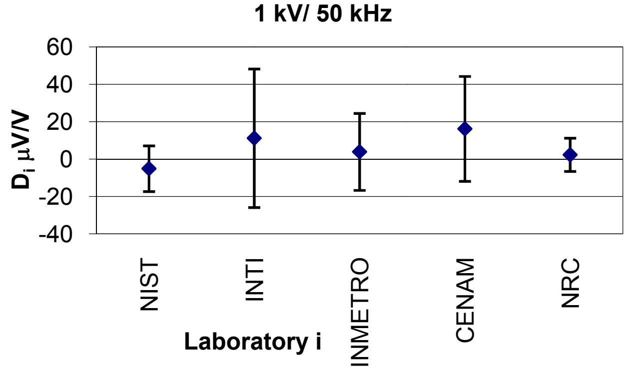
Degree of equivalence D_i and its uncertainty U_{D_i} at 1 kV /20 kHz, in μV/V.

1 kV / 20 kHz					
$\delta_{SIM.EM\text{-}K9}$= -0.7 μV/V ; $U_{\delta_{SIM.EM\text{-}K9}}$ = 8.0 μV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}	k
NIST	1.0	14.1	1.7	11.8	2.0
INTI	6.1	33.0	6.8	33.1	2.1
UTE	11.0	11.0	11.7	23.8	2.0
INMETRO	-2.0	18.0	-1.3	19.9	2.0
CENAM	3.9	17.0	4.6	18.6	2.1
NRC	-2.2	10.0	-1.5	6.2	2.0



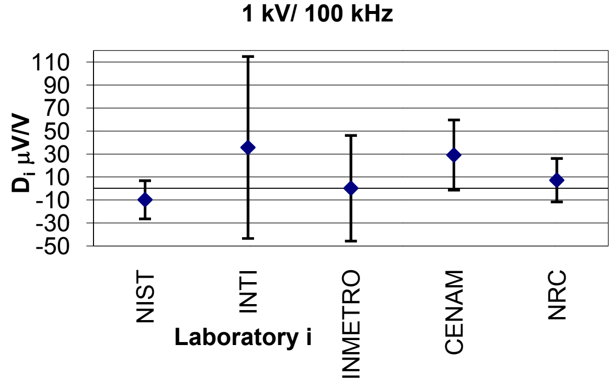
Degree of equivalence D_i and its uncertainty U_{D_i} at 1 kV /50 kHz, in μV/V

1 kV / 50 kHz					
$\delta_{SIM.EM\text{-}K9}$= -12.9 μV/V ; $U_{\delta_{SIM.EM\text{-}K9}}$ = 9.7 μV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}	k
NIST	-18.0	15.4	-5.1	12.2	2.0
INTI	-1.7	37.0	11.2	37.1	2.1
INMETRO	-9.0	18.0	3.9	20.6	2.0
CENAM	3.3	27.0	16.2	28.0	2.2
NRC	-10.6	13.0	2.3	8.9	2.0



Degree of equivalence D_i and its uncertainty U_{D_i} at 1 kV /100 kHz, in µV/V

<table>
<tr><th colspan="6">1 kV / 100 kHz</th></tr>
<tr><td colspan="6">$\delta_{SIM.EM-K9}$= -25.2 µV/V ; $U_{\delta_{SIM.EM-K9}}$ = 16.8 µV/V</td></tr>
<tr><td>Laboratory i</td><td>δ_i</td><td>$U_{\delta i}$</td><td>D_i</td><td>U_{Di}</td><td>k</td></tr>
<tr><td>NIST</td><td>-35.0</td><td>23.4</td><td>-9.8</td><td>16.6</td><td>2.0</td></tr>
<tr><td>INTI</td><td>10.5</td><td>74.0</td><td>35.7</td><td>79.1</td><td>2.2</td></tr>
<tr><td>INMETRO</td><td>-25.0</td><td>42.0</td><td>0.2</td><td>46.0</td><td>2.0</td></tr>
<tr><td>CENAM</td><td>3.9</td><td>27.0</td><td>29.1</td><td>30.5</td><td>2.1</td></tr>
<tr><td>NRC</td><td>-18.0</td><td>25.0</td><td>7.2</td><td>18.9</td><td>2.0</td></tr>
</table>



The results at 1 kV show a degree of equivalence smaller than 4 µV/V at 1 kHz; 7 µV/V at 10 kHz; 12 µV/V at 20 kHz; 17 µV/V at 50 kHz and 36 µV/V at 100 kHz. All the differences between the reported values and the reference value are within the uncertainty reported by the participants.

10.3 Degree of equivalence SIM.EM-K11

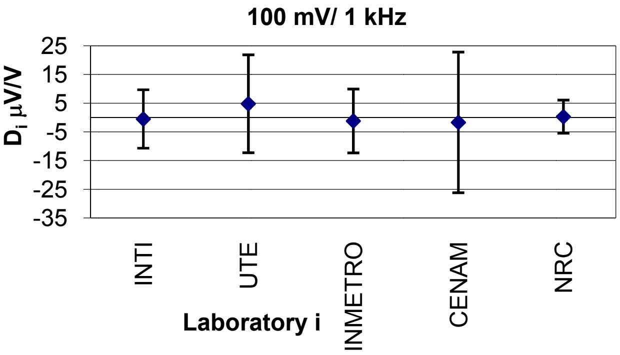
At 100 mV, the reference values were evaluated as the weighted mean of values from NRC and INTI. As mentioned in section 6, the values of UTE, INTI and CENAM have traceability to the PTB standards at 3 V and 1 V, whereas INMETRO have traceable values to PTB standards at 100 mV.

Correlation between UTE, INMETRO and CENAM may exist with respect to the INTI values at 1 V and 3 V, but the measurement process, associated with the step down procedures, ensures that the uncertainty at 1 V and 3 V is very low compared with the uncertainty at 100 mV. The effects of the correlation between the laboratories can be considered negligible at 100 mV.

At the CCEM K-11 errors were considered due to the power supply voltage and to the temperature and the humidity coefficients of the travelling standard, but they have been considered insignificant [9].

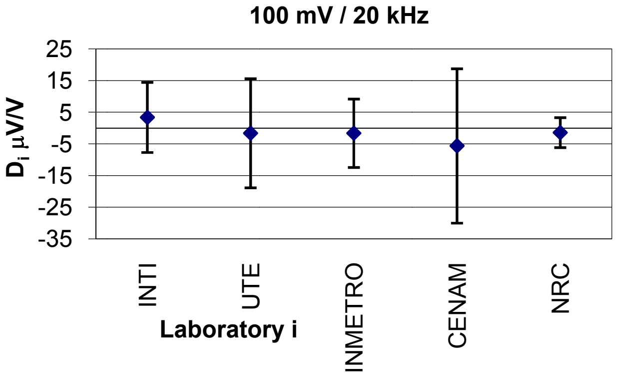
Degree of equivalence D_i and its uncertainty U_{D_i} at 100 mV /1 kHz, in µV/V; for k=2.0

<table>
<tr><th colspan="5">100 mV / 1 kHz</th></tr>
<tr><td colspan="5">$\delta_{SIM.EM-K11}$= 9.2µV/V ; $U_{\delta_{SIM.EM-K11}}$ =7.8 µV/V</td></tr>
<tr><td>Laboratory i</td><td>δ_i</td><td>$U_{\delta i}$</td><td>D_i</td><td>U_{Di}</td></tr>
<tr><td>INTI</td><td>8.7</td><td>12.6</td><td>-0.5</td><td>10.2</td></tr>
<tr><td>UTE</td><td>14.0</td><td>7.5</td><td>4.8</td><td>17.1</td></tr>
<tr><td>INMETRO</td><td>8.0</td><td>8.0</td><td>-1.2</td><td>11.1</td></tr>
<tr><td>CENAM</td><td>7.5</td><td>23.0</td><td>-1.7</td><td>24.5</td></tr>
<tr><td>NRC</td><td>9.5</td><td>9.5</td><td>0.3</td><td>5.8</td></tr>
</table>



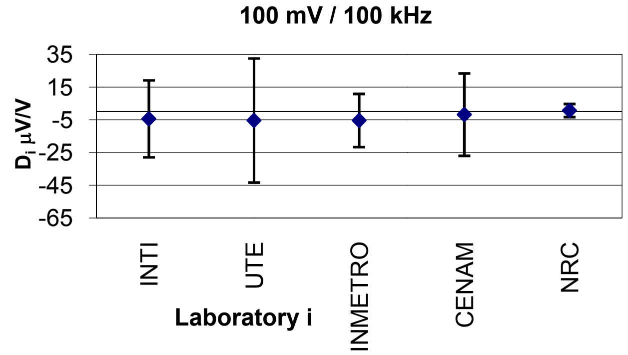
Degree of equivalence D_i and its uncertainty U_{D_i} at 100 mV /20 kHz, in µV/V; for k=2.0

<table>
<tr><th colspan="5">100 mV / 20 kHz</th></tr>
<tr><td colspan="5">$\delta_{SIM.-EM-K11}$= -0.4 µV/V ; $U_{\delta_{SIM.EM-K11}}$ = 7.3 µV/V</td></tr>
<tr><td>Laboratory i</td><td>δ_i</td><td>$U_{\delta i}$</td><td>D_i</td><td>U_{Di}</td></tr>
<tr><td>INTI</td><td>3.0</td><td>13.0</td><td>3.4</td><td>11.1</td></tr>
<tr><td>UTE</td><td>-2.0</td><td>7.7</td><td>-1.6</td><td>17.2</td></tr>
<tr><td>INMETRO</td><td>-2.0</td><td>8.0</td><td>-1.6</td><td>10.8</td></tr>
<tr><td>CENAM</td><td>-6.0</td><td>23.0</td><td>-5.6</td><td>24.4</td></tr>
<tr><td>NRC</td><td>-1.8</td><td>8.5</td><td>-1.4</td><td>4.7</td></tr>
</table>



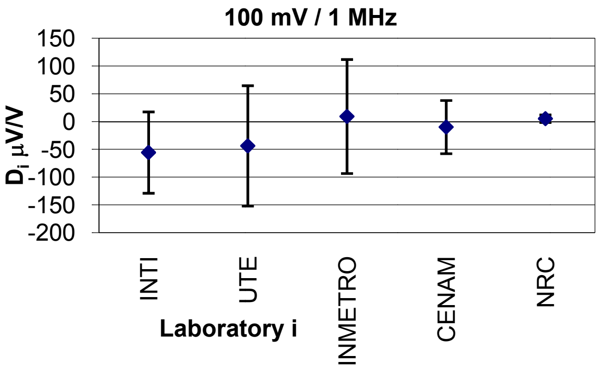
Degree of equivalence D_i and its uncertainty U_{D_i} at 100 mV /100 kHz, in µV/V; for k=2.0

<table>
<tr><th colspan="5">100 mV / 100 kHz</th></tr>
<tr><td colspan="5">$\delta_{SIM.EM-K11}$= 23.4 µV/V ; $U_{\delta_{SIM.EM-K11}}$ = 9.9µV/V</td></tr>
<tr><td>Laboratory i</td><td>δ_i</td><td>$U_{\delta i}$</td><td>D_i</td><td>U_{Di}</td></tr>
<tr><td>INTI</td><td>19.0</td><td>25.0</td><td>-4.4</td><td>23.5</td></tr>
<tr><td>UTE</td><td>18.0</td><td>18.0</td><td>-5.4</td><td>37.9</td></tr>
<tr><td>INMETRO</td><td>18.0</td><td>13.0</td><td>-5.4</td><td>16.3</td></tr>
<tr><td>CENAM</td><td>21.6</td><td>23.0</td><td>-1.8</td><td>25.2</td></tr>
<tr><td>NRC</td><td>24.1</td><td>10.3</td><td>0.7</td><td>4.0</td></tr>
</table>



Degree of equivalence D_i and its uncertainty U_{D_i} at 100 mV /1 MHz, in µV/V; for k=2.0

<table>
<tr><th colspan="5">100 mV / 1 MHz</th></tr>
<tr><td colspan="5">$\delta_{SIM.-EM-K11}$=69.8 µV/V ; $U_{\delta_{SIM.EM-K11}}$ = 23.1 µV/V</td></tr>
<tr><td>Laboratory i</td><td>δ_i</td><td>$U_{\delta i}$</td><td>D_i</td><td>U_{Di}</td></tr>
<tr><td>INTI</td><td>14.0</td><td>75.0</td><td>-55.8</td><td>73.2</td></tr>
<tr><td>UTE</td><td>26.0</td><td>52.0</td><td>-43.8</td><td>108.4</td></tr>
<tr><td>INMETRO</td><td>79.0</td><td>98.0</td><td>9.2</td><td>102.7</td></tr>
<tr><td>CENAM</td><td>59.9</td><td>42.0</td><td>-9.9</td><td>47.9</td></tr>
<tr><td>NRC</td><td>75.0</td><td>23.0</td><td>5.2</td><td>6.9</td></tr>
</table>



The results at 100 mV show a degree of equivalence smaller than 5 µV/V at 1 kHz, 6 µV/V at 20 kHz 6 µV/V at 100 kHz, and smaller than 55 µV/V at 1 MHz. All the differences between the reported values and the reference value are within the uncertainty reported by the participants.

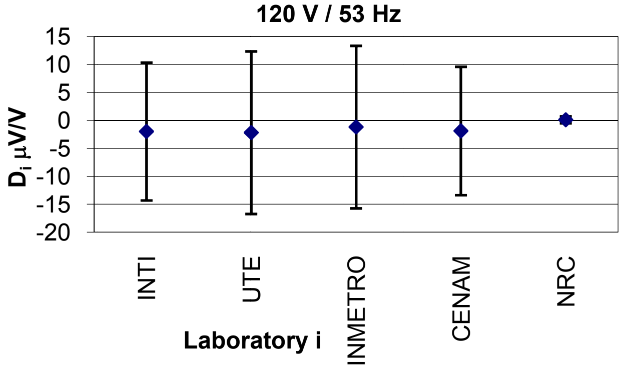
10.4 Degree of equivalence at 120 V/ 53 Hz

At 120 V and 53 Hz, the reference value was evaluated as the weighted mean of values from NRC and INTI. The values of INTI and CENAM are traceable to the PTB standards at 1 V, whereas INMETRO and UTE have traceable values to PTB standards at 100 V and 120 V, respectively.

Correlation between UTE, INMETRO and CENAM may exist with respect to INTI values at 1 V, but the long measurement process, associated with the voltage step up procedures, makes the uncertainty at 1 V low compared with the uncertainty at 120 V. The effects of the correlation between the laboratories at 1 V level can be considered negligible at 120 V.

Degree of equivalence D_i and its uncertainty U_{D_i} at 120 V /53 Hz, in µV/V

120 V / 53Hz					
$\delta_{SIM.EM-1.9}$= 4.2 µV/V ; $U_{\delta_{SIM.EM\ 1.9}}$ =2.8 µV/V					
Laboratory i	δ_i	$U_{\delta i}$	D_i	U_{Di}	k
INTI	2.2	12.0	-2.0	12.3	2.1
UTE	2.0	7.0	-2.2	14.5	2.0
INMETRO	3.0	14.0	-1.2	14.5	2.0
CENAM	2.3	11.0	-1.9	11.5	2.0
NRC	4.3	2.7	0.1	0.6	2.1



The results at 120 V show for all participants a degree of equivalence smaller than 3 µV/V. All the differences between the reported values and the reference value are within the uncertainty declared by the participants.

11. Link with the CCEM Key Comparison

The results of CCEM-K6a, CCEM-K9 and CCEM-K11 key comparisons are available. Rather than evaluating the differences between the pairs of laboratories, only the differences between the results of participants in the SIM comparison, not participating in the CCEM comparisons, and the CCEM key comparison reference value (KCRV) were calculated.

The link between a result of an i-th laboratory participating in the SIM comparison with respect to the reference value of the corresponding CCEM key comparison is estimated using (10) [5].

$$D_{link_i} = \delta_{i_{SIM}} - \delta_{KCRV} = (\delta_{i_{SIM}} - \delta_{SIM}) + (\delta_{SIM} - \delta_{KCRV}) \qquad (10)$$

where:

$\delta_{i\ SIM}$	is the reported value of the i-th laboratory participating in the SIM comparison,
δ_{KCRV}	is the reference value of the corresponding CCEM comparison,
$\delta_{i\ SIM} - \delta_{SIM}$	is the degree of equivalence of the i-th laboratory participating in SIM comparison with respect to the reference value of SIM comparison, evaluated in the section 10 of this document (D_i),
$\delta_{SIM} - \delta_{KCRV}$	is the difference between the references values of both comparisons. This term will be evaluated using the weighted mean of the differences between reference values of the laboratories participating in both comparisons, [5].

The last term of (10) can be evaluated using the values of the laboratories participating in the determination of the reference values of SIM and CCEM:

$$(\delta_{SIM} - \delta_{KCRV})_i = (\delta_{i_{CCEM}} - \delta_{KCRV}) - (\delta_{i_{SIM}} - \delta_{SIM}) \tag{11}$$

Equation (11) is equivalent to:

$$(\delta_{SIM} - \delta_{KCRV})_i = D_{i_{CCEM}} - D_{i_{SIM}} \tag{12}$$

The weighted mean of the differences between the reference values equals

$$\delta_{SIM} - \delta_{KCRV} = \frac{\sum_{i=1}^{n} (D_{i\,CCEM} - D_{i_{SIM}})/u^2_{(D_{i\,CCEM} - D_{i\,SIM.})}}{\sum_{i=1}^{n} 1/u^2_{(D_{i\,CCEM} - D_{i\,SIM})}} \tag{13}$$

Each difference D_i has its own uncertainty, $u_{D_{i\,SIM}}$, $u_{D_{i\,CCEM}}$, then the expanded uncertainty of the difference between reference values was estimated as the root of the sum square of the u_{D_i} as follows:

$$u_{(D_{i\,CCEM} - D_{i\,SIM})_i} = \sqrt{u^2_{D_{i\,SIM}} + u^2_{D_{iCCEM}}} \tag{14}$$

The uncertainty of the weighted mean of the differences between reference values is then:

$$u_{(\delta_{SIM} - \delta_{KCRV})} = \frac{1}{\sqrt{\sum_{i=1}^{n} \frac{1}{u^2_{(D_{i_{SIM}} - D_{i_{CCEM}})}}}} \tag{15}$$

Finally the uncertainty of $D_{link\ i}$ is equal to:

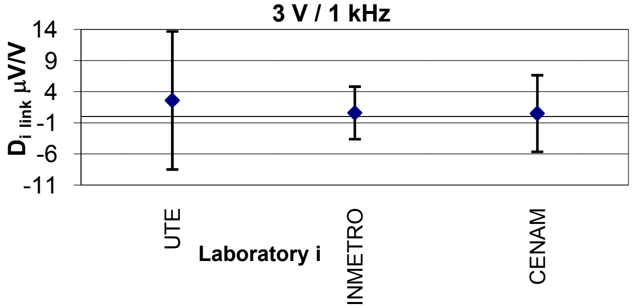
$$U_{D_{link\ i}} = k\sqrt{u^2_{D_{i_{SIM}}} + u^2_{(\delta_{SIM} - \delta_{KCRV})}} \tag{16}$$

with k=2, because the participants reported results at k =2.0 and the references values at SIM and CCEM comparisons were reported at k =2.0.

11.1 Link SIM.EM-K6a – CCEM-K6a

Link with the CCEM-K6a, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 3 V / 1 kHz, in µV/V

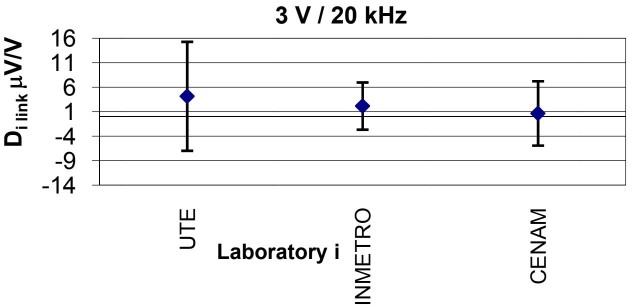
3 V / 1 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	2.6	11.1
INMETRO	0.6	4.2
CENAM	0.5	6.1



3 V / 1 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K6a	0.3	1.2				
CCEM-K6a	0.0	0.4				
NIST			-0.3	3.0	-0.2	1.0
NRC			0.0	0.4	-0.1	0.6

Link with the CCEM-K6a, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 3 V / 20 kHz, in µV/V

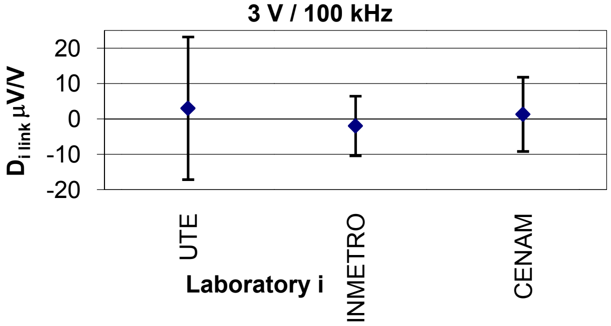
3 V / 20 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	4.2	11.1
INMETRO	2.2	4.8
CENAM	0.7	6.6



3 V / 20 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K6a	2.3	2.1				
CCEM-K6a	0.9	0.5				
NIST			-0.3	2.4	0.4	1.2
NRC			0.2	1.9	0.5	1.1

Link with the CCEM-K6a, $D_{i\ link}$ and its uncertainty $U_{Di\ link}$, at 3 V / 100 kHz, in µV/V

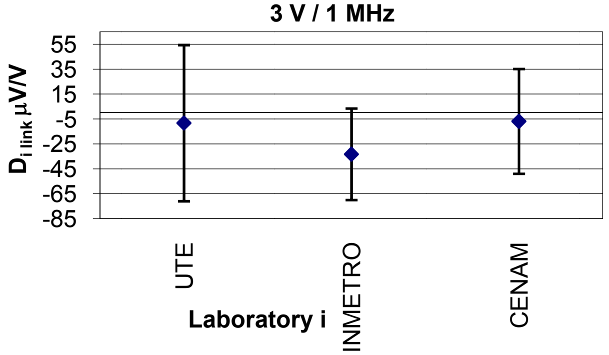
3 V / 100 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	3.0	20.2
INMETRO	-2.0	8.4
CENAM	1.3	10.5



3 V / 100 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K6a	16.3	5.8				
CCEM-K6a	7.2	1.0				
NIST			-0.3	6.7	1.2	1.7
NRC			0.2	4.8	1.4	1.7

Link with the CCEM-K6a, $D_{i\ link}$ and its uncertainty $U_{Di\ link}$, at 3 V / 1 MHz, expressed in µV/V

3 V / 1 MHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	-8.2	62.6
INMETRO	-33.2	36.7
CENAM	-6.8	42.1

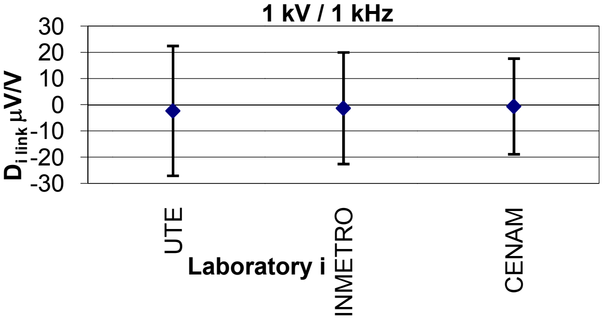


3 V / 1 MHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K6a	5,6	12,4				
CCEM-K6a	121	6,7				
NIST			-4,6	12,6	8,0	20
NRC			4,4	12,3	-10,0	11

11.2 Link SIM.EM-K9 – CCEM-K9

Link with the CCEM-K9, $D_{i\ link}$ and its uncertainty $U_{Di\ link}$, at 1 kV / 1 kHz, in μV/V

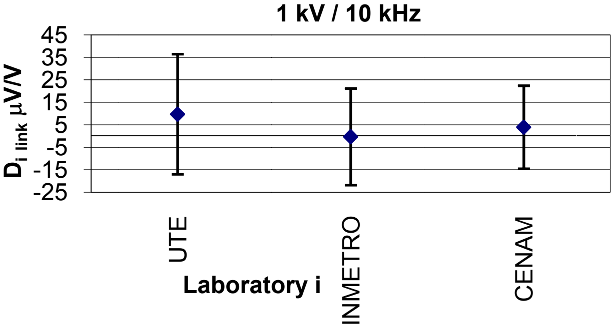
1 k V / 1 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	-2.3	24.8
INMETRO	-1.3	21.3
CENAM	-0.6	18.3



1 kV / 1 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K9	7.6	6.9				
CCEM-K9	0.2	3.1				
NIST			2.4	9.5	7.2	16.8
NRC			-0.9	7.4	0.3	9.6
INTI			-2.4	14.8	-4.7	13.8

Link with the CCEM-K9, $D_{i\ link}$ and its uncertainty $U_{Di\ link}$, at 1 kV / 10 kHz, in μV/V

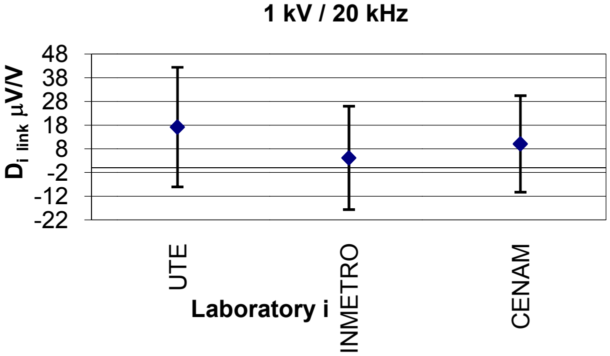
1 k V / 10 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ link}$
UTE	9.7	26.7
INMETRO	-0.3	21.5
CENAM	3.9	18.5



1 kV / 10 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K9	3.3	7.2				
CCEM-K9	-2.3	3.4				
NIST			0.7	9.4	3.9	16.8
NRC			-0.4	7.8	3.7	9.5
INTI			-0.1	20.9	-2.3	15.7

Link with the CCEM-K9, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 1 kV / 20 kHz, in µV/V

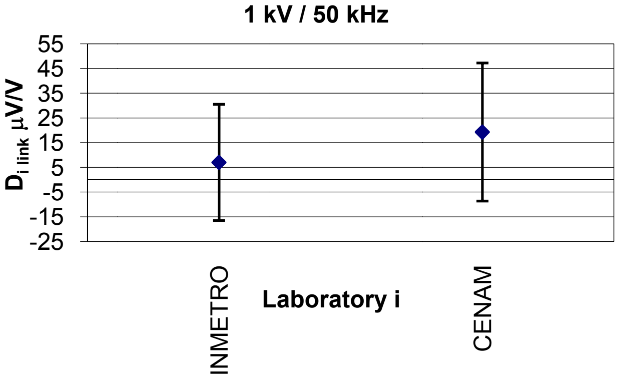
1 k V / 20 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ \ link}$
UTE	17.2	25.2
INMETRO	4.2	21.8
CENAM	10.1	20.3



1 kV / 20 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K9	-0.7	8.0				
CCEM-K9	-5.2	3.7				
NIST			1.7	11.8	5.7	15.9
NRC			-1.5	6.2	6.0	9.4
INTI			6.8	33.1	-5.0	19.7

Link with the CCEM-K9, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 1 kV / 50 kHz, in µV/V

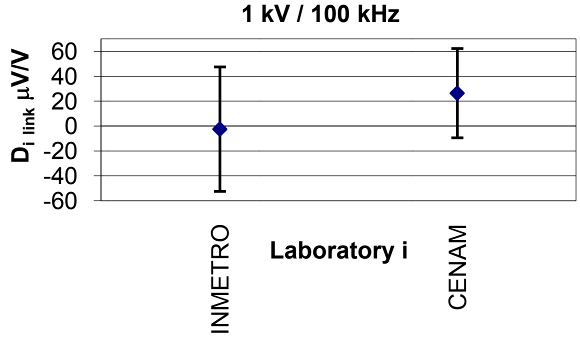
1 k V / 50 kHz		
Laboratory i	$D_{i\ link}$	$U_{Di\ \ link}$
INMETRO	7.0	23.5
CENAM	19.3	29.4



1 kV / 50 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K9	-12.9	9.7				
CCEM-K9	-19.9	5.0				
NIST			-5.1	12.2	-3.3	20.9
NRC			2.3	8.9	7.9	11.0
INTI			11.2	37.1	-4.1	23.6

Link with the CCEM-K9, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 1 kV / 100 kHz, in µV/V

1 k V / 100 kHz		
Laboratory i	$D_{i\ link}$	$U_{D_{i\ link}}$
INMETRO	-2.5	50.0
CENAM	26.4	35.8

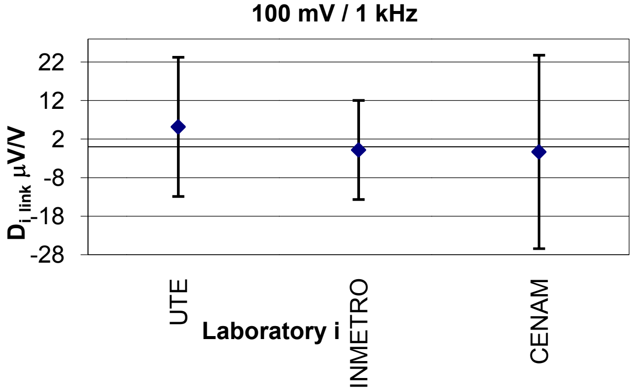


1 kV / 100 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{i SIM}}$	$D_{i CCEM}$	$U_{D_{i\ CCEM}}$
SIM.EM-K9	-25.2	16.8				
CCEM-K9	-53.1	10.0				
NIST			-9.8	16.6	-6.1	27.4
NRC			7.2	18.9	-0.7	21.8
INTI			35.7	79.1	-2.7	38.7

11.3 Link SIM.EM-K11- CCEM-K11

Link with the CCEM-K11, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 100 mV / 1 kHz, in µV/V

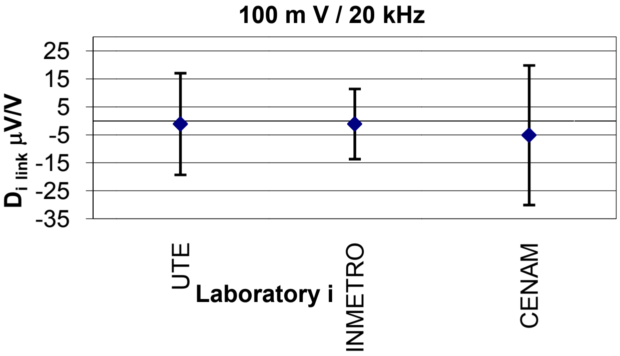
100 mV / 1 kHz		
Laboratory i	$D_{i\ link}$	$U_{D_{i\ link}}$
UTE	5.2	18.1
INMETRO	-0.8	12.8
CENAM	-1.3	25.1



100 mV / 1 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{i SIM}}$	$D_{i CCEM}$	$U_{D_{i\ CCEM}}$
SIM.EM-K11	9.2	7.8				
CCEM- K11	-0.5	2.3				
INTI			-0.5	10.2	-0.1	9.9
NRC			0.3	5.8	0.7	4.8

Link with the CCEM-K11, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 100 mV / 20 kHz, in µV/V

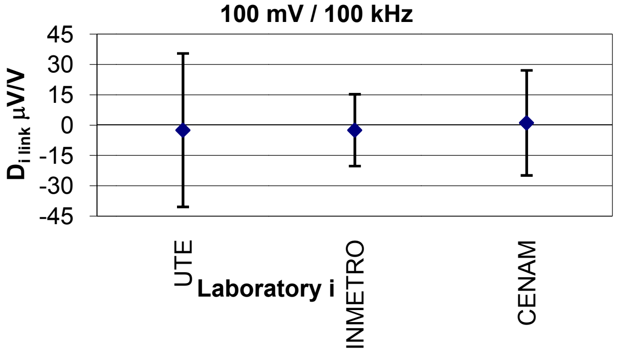
100 mV / 20 kHz		
Laboratory i	$D_{i\ link}$	$U_{D_{i\ link}}$
UTE	-1.1	18.2
INMETRO	-1.1	12.5
CENAM	-5.1	24.9



100 mV / 20 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K11	-0.4	7.3				
CCEM- K11	-0.3	2.9				
INTI			3.4	11.1	0.9	9.8
NRC			-1.4	4.7	-0.2	5.6

Link with the CCEM-K11, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 100 mV / 100 kHz, in µV/V

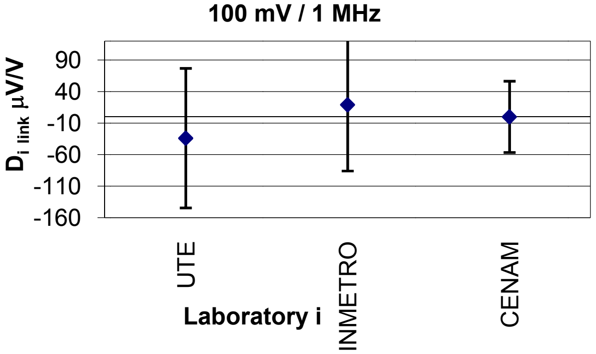
100 mV / 100 kHz		
Laboratory i	$D_{i\ link}$	$U_{D_{i\ link}}$
UTE	-2.5	38.0
INMETRO	-2.5	17.8
CENAM	1.1	26.0



100 mV / 100 kHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K11	23.4	9.9				
CCEM- K11	1.6	4.5				
INTI			-4.4	23.5	-0.2	20.8
NRC			0.7	4.0	3.5	6.6

Link with the CCEM-K11, $D_{i\ link}$ and its uncertainty $U_{D_{i\ link}}$, at 100 mV / 1 MHz, in µV/V

100 mV / 1 MHz		
Laboratory i	$D_{i\ link}$	$U_{D_{i\ link}}$
UTE	-34.1	110.7
INMETRO	18.9	105.1
CENAM	-0.2	56.6



100 mV / 1 MHz	δ_{KCRV}	$U_{\delta_{KCRV}}$	$D_{i\ SIM}$	$U_{D_{iSIM}}$	D_{iCCEM}	$U_{D_{i\ CCEM}}$
SIM.EM-K11	69.8	23.1				
CCEM- K11	-7	27				
INTI			-55.8	73.2	-30.0	62
NRC			5.2	6.9	13.0	32

12. Corrective actions:

Concerning the INTI results at 3 V, last July 2007, the ac-dc transfer laboratory of INTI was audited by Dr. Klonz from PTB, at that time INTI compared their measurement at 3 V against the PTB values. The results are shown in the following table, they are in agreement with the PTB results, within the uncertainties declared.

Laboratory	ac-dc voltage transfer difference at 3 V				
	δ_i and $U_{\delta i}$ (k=2,0) µV/V				
		1 kHz	20 kHz	100 kHz	1 MHz
INTI	δ_{INTI}	0.1	0.3	2.8	-27.4
	$U_{\delta\ INTI}$	2.0	3.0	12.0	40.0
PTB	δ_{PTB}	0.1	0.5	3.7	-19.7
	$U_{\delta\ PTB}$	1.0	1.0	3.0	10.0

13. Acknowledgements

CENAM acknowledges the participants for their time invested in doing measurements, preparing reports and dealing with administrative procedures for clearing customs and sending the travelling standard to the next laboratory. Thanks are given to the participants for the comments made on the protocol and the

drafts. Special acknowledgement is given to the participants in the CCEM Key comparisons; NRC, NIST and INTI, because thanks to their participation the link could be extended to the other SIM-region NMIs.

CENAM thanks Dr. Harold Sanchez, at the Instituto Costarricence de Electricidad, for his collaboration. It is also gratefully acknowledged the financial support of the Organization of American States, which made it possible to hand carry the travelling standard in South America.

The collaboration of Dr. David Avilés and Dr. René Carranza from CENAM, for their comments on the protocol and on the Drafts is gratefully acknowledged.

14. References

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APPENDIX A

REPORTS OF THE PARTICIPANTS

REPORT OF RESULTS
SIM.EM-K6 a.

Participating laboratory: Institute for National Measurement Standards, NRC, Canada
Date of measurements: September 2004 – October 2004
Description of the measuring method:

The Traveling Standard was compared to an NRC working standard designated V4-GM10-03N, a MJTC (10 mA, 400 Ω heater resistance.) Both artifacts were connected in parallel using an NRC Special Tee SPT2 (one arm type GR874 connector, second arm type N connector, c.f. reference [5].) The test voltage was applied simultaneously to both artifacts in a sequence AC - DC N - DC R - AC. The output voltages of both artifacts were measured after 45 s stabilization time. The output voltage of the traveling standard was measured using a 7½ or 8½ digit voltmeter. The output voltage of the working standard was measured using a nanovoltmeter. The NRC AC-DC Transfer Comparator used is described in detail in references [1] –[3].

Connection diagrams: See Appendix II.
Environmental conditions of the measurement: (22.5 ± 1) °C, (40 ± 10) % RH

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Expanded Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
3 V / 1 kHz	0.3	1.2	2
3 V / 20 k Hz	2.5	2.8	2
3 V / 100 kHz	16.5	7.2	2
3 V / 1 MHz	10	17	2

The reference standard, and its traceability to SI.

NRC maintains an independent realization of primary standards of AC-DC transfer difference.

NRC primary standard of AC-DC voltage transfer difference is a group of four 1-V Multijunction Thermal Converters. Average of the group is assumed to have a negligible AC-DC voltage transfer difference in the 20 Hz -5 kHz frequency band. The frequency band of NRC working standards is extended to 100 MHz by using a set of NRC-designed Calorimetric Thermal Voltage Converters. NRC has participated in a Key Comparison CCEM-K6a. Results of this comparison have shown a very good agreement between the NRC primary standards AC-DC transfer difference and the Key Comparison Reference Value in the 1 kHz – 1 MHz frequency range.

The AC-DC difference of the NRC working standard V4-GM10-03N was determined by comparison to a 2-V MJTC V2-GM20-93-1, which in turn was calibrated using a converter designated MJTC V1-GM20-66, a member of the primary standards group, and a "calculable" calorimetric voltage converter designated CTVC#17.

The detailed description of NRC primary standards is described in references [1]-[3].

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the ISO Guide to the Expression of Uncertainty in Measurements 1995.

SIM .EM K6 a. (3 V)																								
Uncertainty component	Estimate x_i				Relative standard uncertainty $u(x_i)$				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				Uncertainty contribution $u(\delta_i)$				Degrees of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard: V4-GM10-03N																								
• Reference Standard calibration	-0.5	0.6	5.2	-3	0.4	1.2	1.9	6.6	A+B	A+B	A+B	A+B	1	1	1	1	0.4	1.2	1.9	6.6	29.2	36.1	15.2	9.2
• Reference standard stability																								
•																								
•																								
Difference measurement:	0.3	2.5	16.5	10																				
• Standard deviation of measurements					0.1	0.2	0.2	0.2	n/A	n/A	n/A	n/A	1	1	1	1	0.1	0.2	0.2	0.2	7	6	7	7
• Magnitude dependent/exponent n					0.1	0.7	0.4	0.7	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.1	0.7	0.4	0.7	4.9	4.9	4.9	4.9
• Closure uncertainty					0.5	0.8	3.0	9	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.5	0.8	3.0	9	4.9	4.9	4.9	4.9
• Tee connector																								
•																								
•																								
δ	0.3	2.5	16.5	10.0													ν_{eff}				14	47	10	14

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K11

Participating laboratory: Institute for National Measurement Standards, NRC, Canada

Date of measurements: September 2004 – October 2004

Description of the measuring method

The Traveling Standard was compared to an NRC working standard designated V05b, a SJTC (2.5 mA, 205 Ω heater resistance.) Both artifacts were connected in parallel using an NRC Special Tee SPT2 (one arm type GR874 connector, second arm type N connector, c.f. reference [5].) The test voltage was applied simultaneously to both artifacts in a sequence AC - DC N - DC R - AC. The output voltages of both artifacts were measured after 60 s stabilization time. The output voltage of the traveling standard was measured using a 7½ or 8½ digit voltmeter. The output voltage of the working standard was measured using a nanovoltmeter. The NRC AC-DC Transfer Comparator used is described in detail in references [1] –[3].

Connection diagrams: See Appendix II.

Environmental conditions of the measurement: (22.5 ± 1) °C (40 ± 10) % RH

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Expanded Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
100 mV / 1 kHz	9.5	9.5	2
100 mV / 20 k Hz	-1.8	8.5	2
100 mV / 100 kHz	24.1	10.3	2
100 mV / 1 MHz	75	23	2

The reference standard, and its traceability to SI.

Short description of NRC primary standards of AC-DC voltage transfer difference is given above.
The AC-DC difference of the NRC working standard V505b was determined by comparison to a 1-V SJTC based working standard designated V51N (2.5 mA, 400 Ω input resistance.) It was calibrated by comparison to V2-GM20-93-1, and a "calculable" calorimetric voltage converter designated CTVC#17 (as above.)

NRC has participated in a Key Comparison CCEM-K11. Preliminary results of this comparison, to be published shortly, have shown a very good agreement between the NRC low voltage standards AC-DC transfer difference and the Key Comparison Reference Value.

A detailed description of NRC approach to calibrating low voltage AC-DC difference voltage standards is given in reference [4].

SIM .EM K11.(100 mV)																												
Uncertainty component	Estimate x_i				Relative standard uncertainty $u(x_i)$				Probabilty Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				Uncertainty contribution $u(\delta_i)$				Degrees of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard: VS05b																								
• Reference Standard calibration • Reference standard stability	-2.9	-0.1	40.2	206.8	0.6	1.1	2.0	6.7	A+B	A+B	A+B	A+B	1	1	1	1	0.6	1.1	2.0	6.7	53.2	71	16.9	9.6
• •																								
Difference measurement:	12.4	-1.7	-16.1	-131.5																				
• Standard deviation of measurements					4.5	3.9	4.4	5.2	n/A	n/A	n/A	n/A	1	1	1	1	4.5	3.9	4.4	5.2	13	15	15	15
• Magnitude dependent/exponent α					0.4	0.3	0.7	0.9	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.4	0.3	0.7	0.9	4.9	4.9	4.9	4.9
• F792 input level dependent					0.2	0.3	0.2	2.9	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.2	0.3	0.2	2.9	4.9	4.9	4.9	4.9
• F792 temperature dependent					0.6	0.6	0.6	1.7	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.6	0.6	0.6	1.7	4.9	4.9	4.9	4.9
• Tee connector/adapter					0	0	0	0.1	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0	0	0	0.1	4.9	4.9	4.9	4.9
• Closure uncertainty					1.2	1.2	1.7	7	rect/B	rect/B	rect/B	rect/B	1	1	1	1	1.2	1.2	1.7	7	4.9	4.9	4.9	4.9
• F792 drift					0.1	0.1	0.1	0.4	rect/B	rect/B	rect/B	rect/B	1	1	1	1	0.1	0.1	0.1	0.4	4.9	4.9	4.9	4.9
δ	9.5	-1.8	24.1	75.3													ν_{eff}				18	21	27	23

REPORT OF RESULTS
SIM.EM-K9

Participating laboratory: Institute for National Measurement Standards, NRC, Canada

Date of measurements: September 2004 – October 2004

Description of the measuring method:

The Traveling Standard was compared to an NRC working standard designated TFM4, a PMJTC (10 mA, 90 Ω heater resistance) with a resistive range extender designated FR27 (200 k Ω.) Both artifacts were connected in parallel using an NRC Special Tee SFT2 (one arm type GR874 connector, second arm type N connector, c.f. reference [5].) The test voltage was applied simultaneously to both artifacts in a sequence AC - DC N – AC- DC R - AC. The output voltages of both artifacts were measured after 45 s stabilization time. The output voltage of the traveling standard was measured using a 7½ or 8½ digit voltmeter. The output voltage of the working standard was measured using a nanovoltmeter. The NRC AC-DC Transfer Comparator used is described in detail in references [1] – [3].

Connection diagrams: See Appendix II.

Environmental conditions of the measurement: (23 ± 1) °C, (40 ± 10) % RH

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Expanded Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
1000 V / 1 kHz	6.7	10	2
1000 V / 10 kHz	2.9	10	2
1000 V / 20 kHz	-2.2	10	2
1000 V / 50 kHz	-10.6	13	2
1000 V / 100 kHz	-18	25	2
120 V / 53 Hz	4.3	2.7	2

The reference standard, and its traceability to SI.

Short description of NRC primary standards of AC-DC voltage transfer difference is given above.

The AC-DC difference of the NRC working standard TFM4+FR27 was determined by a usual step-up procedure. We used an NRC-designed set designated S1, consisting of two TVCs, designated VS1n (1 V, 400 Ω) and VS2e (2 V 400 Ω) and four range extending resistors, R1S1 (3 V and 6V), R2S3 (10 V, 20 V), R3S1 (30 V, 60 V), R4S1 (100 V, 200 V). The VS2e with R4S1 range extender was used to calibrate TFM4 with FR27. The TVCs VS1n, VS2e were calibrated either directly or indirectly, using V2-GM20-93-1, using NRC primary standards.

NRC has participated in a Key Comparison CCEM-K9. Preliminary results of this comparison have shown a very good agreement between the NRC high voltage standards AC-DC transfer difference and the Key Comparison Reference Value.

SIM.EM-K9 (1000 V)

Uncertainty component	Estimate x_i					Relative standard uncertainty $u(x_i)$					Probability Distribution / Method of evaluation (A, B)					Sensitivity coefficient c_i					Uncertainty contribution $u_i(\delta)$					Degrees of freedom ν_i				
Frequencies (kHz)	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100
Reference Standard: TFM4+FR27																														
• Reference Standard calibration	0.9	-2.3	-7	-16.3	-8.6	3.9	3.9	4	5	8.7	A+B	A+B	A+B	A+B	A+B	1	1	1	1	1	3.9	3.9	4	5	8.7	105	113	119	32	34
• Reference standard stability																														
•																														
•																														
Difference measurement:	5.8	5.7	5.3	1.8	-17.9																									
• Standard deviation of measurements						0.5	0.5	0.5	0.5	1.5	n/A	n/A	n/A	n/A	n/A	1	1	1	1	1	0.5	0.5	0.5	0.5	1.5	2	2	2	2	2
• Magnitude dependent/exponent *n*						0.4	0.4	0.4	0.4	5.7	rect/B	rect/B	rect/B	rect/B	rect/B	1	1	1	1	1	0.4	0.4	0.4	0.4	5.7	4.9	4.9	4.9	4.9	4.9
• TFM HV correction	0	-0.5	-0.5	3.9	8.4	0.2	0.2	0.2	1.1	2.4	rect/B	rect/B	rect/B	rect/B	rect/B	1	1	1	1	1	0.2	0.2	0.2	1.1	2.4	4.9	4.9	4.9	4.9	4.9
• Closure uncertainty						2	2	2	3	5.8	rect/B	rect/B	rect/B	rect/B	rect/B	1	1	1	1	1	2	2	2	3	5.8	4.9	4.9	4.9	4.9	4.9
• TVC level dependent						2.3	2.3	2.3	2.9	2.9	rect/B	rect/B	rect/B	rect/B	rect/B	1	1	1	1	1	2.3	2.3	2.3	2.9	2.9	4.9	4.9	4.9	4.9	4.9
•																														
δ	6.7	2.9	-2.2	-10.6	-18.1																ν_{eff}					53	56	57	38	39

REPORT OF RESULTS
SIM.EM-SUPPLEMENTARY

Participating laboratory: Institute for National Measurement Standards, NRC, Canada

Date of measurements: September 2004 – October 2004

Description of the measuring method:

The Traveling Standard was compared to an NRC working standard designated V120-GM20-93-2, a MJTC (20 mA, 100 Ω heater resistance) with a resistive range extender (6 kΩ) mounted in a single enclosure. Both artifacts were connected in parallel using an NRC Special Tee SPT2 (one arm type GR874 connector, second arm type N connector, c.f. reference [5].) The test voltage was applied simultaneously to both artifacts in a sequence AC - DC N – DC R - AC. The output voltages of both artifacts were measured after 45 s stabilization time. The output voltage of the traveling standard was measured using a 7½ or 8½ digit voltmeter. The output voltage of the working standard was measured using a nanovoltmeter. The NRC AC-DC Transfer Comparator used is described in detail in references [1] – [3].

Connection diagrams: See Appendix II.

Environmental conditions of the measurement: (23 ± 1) °C, (40 ± 10) % RH

Results of measurements

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Expanded Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
120 V / 53 Hz	4.3	2.7	2

The reference standard, and its traceability to SI.

Short description of NRC primary standards of AC-DC voltage transfer difference is given above.

The AC-DC difference of the NRC working standard V120-GM20-93-2 was determined by comparison of the MJTC at low voltage to a member of the primary standards group. Additional influence of a range extending resistor was estimated experimentally.

SIM.EM-Supplementary (120 V)																																			
Uncertainty component	Estimate x_i					Relative standard uncertainty $u(x_i)$					Probability Distribution / Method of evaluation (A, B)					Sensitivity coefficient c_i					Uncertainty contribution $u_i(\delta)$					Degrees of freedom ν_i				
Frequencies (kHz)	53					53					53					53				1	53					53				
Reference Standard: V120-GM20-93-1	-0.9					1					A+B					1					1					17.1				
• Reference Standard calibration																														
• Reference standard stability																														
•																														
•																														
Difference measurement:	5.2																													
• Standard deviation of measurements						0.2					n/A					1					0.2					6				
• Magnitude dependent/exponent *n*						0.5					rect/B					1					0.5					4.9				
• Closure uncertainty						0.7					rect/B					1					0.7					4.9				
•																														
•																														
•																														
δ	4.3																				ν_{eff}					26				

Appendix I

References

[1] R.F. Clark, P.S. Filipski, D.C. Paulusse, “Improvements in the NRC AC-DC Transfer Capabilities,” *IEEE Trans. Instrum. Meas.*, vol. 46, April 1997, pp. 365 - 368.

[2] P.S. Filipski, R.F. Clark, D.C. Paulusse, “Calorimetric Thermal Voltage Converter as a Wideband Calculable Standard of AC-DC Difference,” *IEEE Trans. Instrum. Meas.*, vol. 48, April 1999, pp. 387-390.

[3] P.S. Filipski, R. Rinfret, “An Automated AC-DC Transfer Calibration System,” *IEEE Trans. Instrum. Meas.*, vol. 49, April 2000, pp. 279-284.

[4] P.S. Filipski, R. Rinfret, “Calibration of a Low Voltage AC-DC Transfer Standard,” IEEE Trans. Instrum. Meas., vol. 47, October 1998, pp. 1067 – 1071.

[5] P.S. Filipski, R.F. Clark, D.C. Paulusse, “Calibration of HF Thermal Voltage Converters using an asymmetrical Tee,” *IEEE Trans. Instrum. Meas.*, vol. 50, April 2001, pp. 345-348.

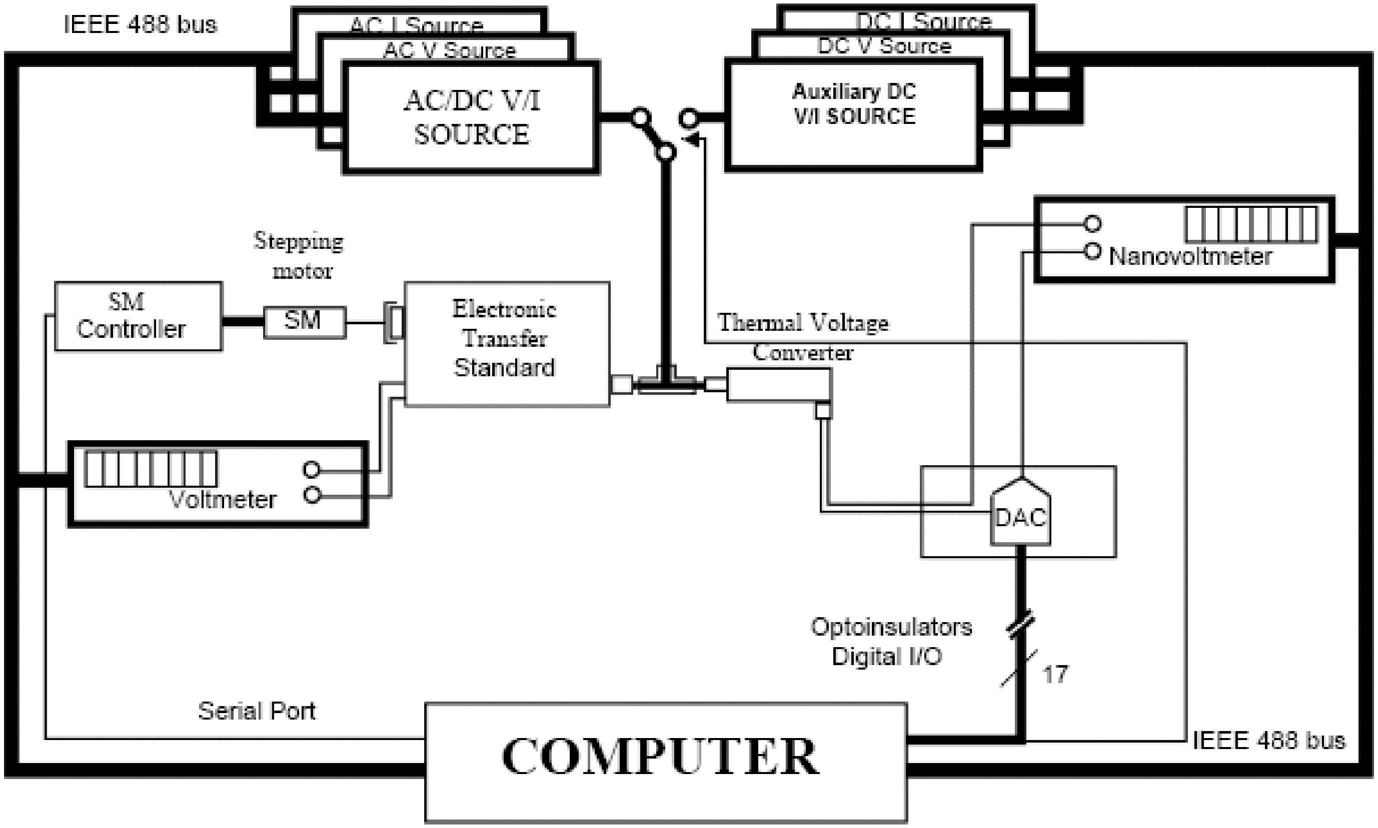

Fig. 1. Simplified circuit diagram of NRC AC-DC voltage transfer comparator.

REPORT OF SPECIAL TEST

THERMAL TRANSFER STANDARD

Fluke Corporation
Model 792A, Serial Number 5685005

Submitted by

Centro Nacional de Metrologia (CENAM)
Querètaro C.P. 76241. Mexico

This thermal transfer standard was tested in January and February 2004 to determine its ac-dc differences, in accordance with NIST Calibration Test Numbers 53350C, 53351C, and 53352C. The instrument was received in a condition suitable for calibration. These calibrations were performed using Fluke 792A battery pack, serial number 5370005, supplied by CENAM.

To calibrate this instrument, ac and dc voltages were applied in a timed sequence to the Type N input connector, and the output emf was taken from the output banana plug terminals and measured using an appropriate thermoelement. This procedure facilitates the calibration process and is not intended to suggest that the instrument should not be used according to its instruction manual. The plane of reference for measurements below 1 MHz was the center of a Type 874 Tee. The unit under test was connected to the plane of reference by a Type 874-to-Type N adapter. For measurements at 1 MHz, the plane of reference was at the center of a Type N Tee. The input low banana plug connector was joined to system ground. The guard, ground, and low banana plug terminals were joined together at the front panel.

REPORT OF SPECIAL TEST

Fluke Model 792A, Serial Number 5685005
Centro Nacional de Metrologia (CENAM)
Querètaro C.P. 76241. Mexico

Determinations were made of the difference between the sinusoidal alternating voltage (less than 1% total harmonic distortion[1]) required for a given output emf and the average of both polarities of direct voltage required for the same emf. The observed differences are given to the nearest microvolt-per-volt (μV/V) in the following tables, where a positive sign indicates that more alternating voltage was required to produce the same emf.

Voltage Range	Applied Voltage	Ac-dc Difference (μV/V)					
V	V	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	1 MHz
7	3	0		+2		+16	+1
1000	1000	+10	+4	+1	-18	-35	

Because this calibration is part of an international intercomparison, the uncertainties quoted in the table below have been reduced from the uncertainties routinely quoted for this instrument. This is therefore classified as a Special Test.

The figures in the table below are the expanded uncertainties ($k = 2$) of the reported values given above, and include both the Type A and Type B components of the uncertainty. Information regarding the calculations of the NIST uncertainties can be found in the in the attached tables.

Voltage Range	Applied Voltage	Uncertainty (μV/V of applied voltage)					
V	V	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz	1 MHz
7	3	3.2		3.2		8.5	17.2
1000	1000	11.6	11.7	14.1	15.4	23.4	

For the Director
National Institute of Standards and Technology

Michael H. Kelley, Leader
Fundamental Electrical Measurements Group
Quantum Electrical Metrology Division

Technical Contact:

Thomas E. Lipe, Physicist
Quantum Electrical Metrology Division
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[1] Owing to their square-law response, thermal converters are inherently insensitive to distortion in the input ac waveform [1,2]. For the ac signals applied to the thermal converters in these tests, the components at frequencies other than the fundamental make negligible contributions to the reported results.

References:

[1] F.L. Hermach, "An investigation of the uncertainties of the NBS thermal voltage and current converters," Natl. Bur. Stand. (U.S.), Report NBSIR 84-2903, April, 1985, Appendix 2. This document is reprinted, for convenience, in the publication cited below.

[2] J.R. Kinard, J.R. Hastings, T.E. Lipe, and C.B. Childers, "AC-DC Difference Calibrations," Natl. Inst. Stand. Tech., Special Pub. 250-27, (May, 1989)

[3] F.L. Hermach, J.R. Kinard, and J.R. Hastings, "Multijunction thermal converters as the NBS primary ac-dc standards for ac current and voltage measurements," IEEE Trans. Instrum. Meas. , IM-36, pp. 300-306, June 1987.

[4] J.R. Kinard and T.X. Cai, "Determination of ac-dc difference in the 0.1-100 MHz frequency range," IEEE Trans. Instrum. Meas. , IM-38, pp. 360-367, April 1989.

[5] T.E. Lipe, "A reevaluation of the NIST low-frequency standards for Ac-dc difference in the voltage range 0.6 – 100 V," IEEE Trans. Instrum. Meas. , IM-45, pp. 913-917, December 1996.

[6] B.N. Taylor and C.E. Kuyatt, "Guidelines for evaluating and expressing the uncertainty of NIST measurement results," NIST Technical Note 1297, September 1994.

Table 1. Uncertainty Analysis for Fluke 792A S/N 5685005 at 3 V

Contribution from NIST Standards	Type	1 kHz	20 kHz	100 kHz	1 MHz
Primary standards MJTCs	B	0.25	0.25		
Comparison of reference TVC to primary standard	B	0.42	0.42		
NIST comparator system	B	0.68	0.68	1.31	2.13
Frequency extension from 1 kHz reference TVC	B		0.29	1.15	3.46
Thermoelement model	B			0.60	3.18
Transimpedance of resistor	B			0.80	5.20
Current standing wave	B			0.80	5.20
Tee and connector contributions	B			0.90	4.50
Skin effect	B			0.50	3.18
Total contribution from NIST standard TVC (k=1)		0.84	0.89	2.40	10.54
Measurement of Fluke 792A to NIST standards.					
Type A component (pooled standard deviation) and number of points measured	A	0.26 N=96	0.26 N=72	0.25 N=72	0.26 N=72
NIST comparator system	B	0.68	0.68	1.31	2.13
Contribution of Fluke 792A S/N 5685005					
Level coefficient	B	0.50	0.50	1.00	2.00
Self-heating	B	0.25	0.25	0.75	1.00
Ac effects	B	1.00	1.00	3.00	8.00
Total contribution of measurement of Fluke 792A		1.36	1.36	3.51	8.58
Standard uncertainty (k = 1)		1.60	1.63	4.25	8.59
Expanded uncertainty (k = 2)		**3.20**	**3.26**	**8.50**	**17.17**
Degrees of freedom		**93**	**71**	**71**	**70**

Table 2. Uncertainty Analysis for Fluke 792A S/N 5685005 at 1000 V

Contribution from NIST Standards	Type	1 kHz	10 kHz	20 kHz	50 kHz	100 kHz
Primary standards MJTCs	B	0.25	0.25			
Comparison of reference TVC to primary standard	B	0.42	0.42			
NIST comparator system	B	0.68	0.68	0.68	0.94	1.31
Frequency extension from 1 kHz reference TVC	B		0.14	0.29	0.72	1.15
Pooled standard deviation for build-up from 10 V to 100 V	A	0.47	0.47	0.52	0.57	0.60
NIST comparator system	B	0.68	0.68	0.68	0.94	1.31
Contribution from TVCs	B	0.12	0.12	0.17	0.23	0.40
Uncertainty for each step in NIST reference build-up		1.18	1.19	1.24	1.70	2.35
10 V to 20 V		1.25	1.26	1.31	1.85	2.35
20 V to 30 V		1.72	1.73	1.80	2.51	3.32
30 V to 50 V		2.08	2.10	2.18	2.70	4.07
50 V to 100 V		2.39	2.41	2.50	3.19	4.70
Pooled standard deviation for build-up from 100 V to 500 V	A	0.50	0.50	0.55	0.62	0.68
NIST comparator system	B	0.94	0.94	0.94	1.21	1.57
Contribution from TVCs	B	0.52	0.52	0.72	1.15	1.67
Uncertainty for each step in NIST reference build-up		1.45	1.46	1.56	2.19	3.00
100 V to 200 V		2.79	2.82	2.94	3.87	5.58
200 V to 300 V		3.14	3.17	3.33	4.45	6.33
300 V to 500 V		3.46	3.49	3.68	5.00	7.00
Pooled standard deviation for transfer from 500 V to 600 V	A	0.70	0.70	0.75	0.82	1.00
NIST comparator system	B	0.94	0.94	0.94	1.21	1.57
Contribution from TVCs	B	0.52	0.52	0.72	1.15	1.67
Reference TVC at 600 V		3.69	3.72	3.94	5.33	7.43
Pooled standard deviation for build-up from 600 V to 1000 V	A	0.70	0.70	0.75	0.82	1.00
NIST comparator system	B	0.94	0.94	0.94	1.21	1.57
Contribution from TVCs	B	0.52	0.52	0.72	1.15	1.67
Uncertainty for 1000 V reference		3.91	3.93	4.18	5.65	7.84
Pooled standard deviation of comparison of Fluke 792 to reference	A	0.76 N=48	0.89 N=48	0.89 N=48	0.63 N=48	1.19 N=72
NIST comparator system	B	0.94	0.94	0.94	1.21	1.57
Contribution of Fluke 792A S/N 5685005						
Level coefficient	B	2.00	2.00	2.50	3.00	5.00
Self-heating	B	3.00	3.00	3.00	3.00	5.00
Ac effects	B	2.00	2.00	3.00	3.00	5.00

Total contribution of measurement of Fluke 792A		4.30	4.32	5.09	5.19	8.66
Standard uncertainty (k = 1)		5.81	5.84	7.04	7.68	11.68
Expanded uncertainty (k = 2)		**11.62**	**11.68**	**14.10**	**15.35**	**23.36**
Degrees of freedom		**47**	**46**	**47**	**46**	**69**

REPORT OF RESULTS
SIM.EM-K11
100 mV

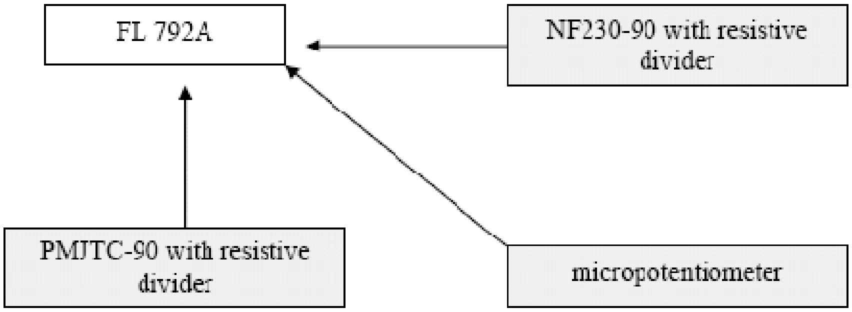
Participating laboratory: INTI, Instituto Nacional de Tecnología Industrial

Date of measurements: 4th March 2004 to 16th April 2004

Description of the measuring method:

At 100 mV the travelling standard was calibrated against two Planar Multijunction Thermal Converter toghether with a Resistive Voltage Divider, ratio 10/1. It was also calibrated using a 15 mA micropotentiometer manufactured by Ballentine Laboratories with a disc resistor of 6,84 Ω [1,2,3].

The differences among the two methods are within their uncertainties.



These comparisons yield to the following system of equations:

$$\begin{bmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 0 & 1 \\ 0 & 0 & -1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \delta_{NF230-90\,w/divider} \\ \delta_{PMJTC-90\,w/divider} \\ \delta_{micropotentiometer} \\ \delta_{FL792} \end{bmatrix} = \begin{bmatrix} a \\ b \\ c \\ \delta_{NF230-90\,w/divider} \\ \delta_{PMJTC-90\,w/divider} \\ \delta_{micropotentiometer} \end{bmatrix} \qquad (7)$$

i.e.

$$[\mathbf{A}]\cdot[\delta]=[\mathbf{B}] \tag{8}$$

and, using the least square method

$$\delta=(\mathbf{A}^t\cdot\mathbf{A})^{-1}\cdot\mathbf{A}^{-1}\cdot\mathbf{B}=\mathbf{C}\cdot\mathbf{B} \tag{9}$$

According to the method described in [1] the associated uncertainties of [δ] are calculated as the square root of the diagonal terms of the covariance matrix

$$\mathrm{cov}(\delta)=\mathbf{C}\cdot\mathrm{cov}(\mathbf{B})\cdot\mathbf{C}^t \tag{10}$$

and cov(B) is the covariance matrix of B. The diagonal terms of cov(B) are:

$$\mathrm{var}(i)=u_A^2(i)+u_C^2(i)+u_M^2(i) \qquad \text{i=a,b,c} \tag{11}$$

where

$u_A(i)$ is the Type A standard uncertainty
$u_C(i)$ is the standard uncertainty of the comparison of two standards
$u_M(i)$ is the standard uncertainty of the scheme of the comparison

Table II presents the components of the covariance of B matrix at 100 mV. The correlation between the thermal converters and the micropotentiometer is equal to 1.

Table II – Uncertainty components at 100 mV

	$u_A(a)$	$u_C(a)$	$u_M(a)$	$u(\delta_{micropot})$
1 kHz	0,6	1,0	1,5	6,0
20 kHz	0,4	1,0	1,1	6,0
100 kHz	0,4	2,0	2,3	12,0
1 MHz	0,4	7,0	2,8	36,0

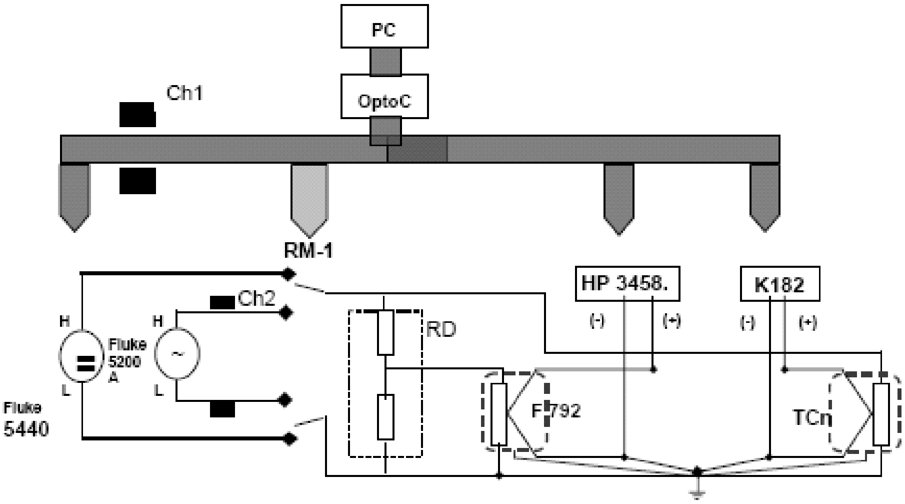
For example, at 1 MHz we get

$$\operatorname{cov}(B)=\begin{bmatrix} 44{,}26 & 0 & 0 & 0 & 0 & 0 \\ 0 & 44{,}27 & 0 & 0 & 0 & 0 \\ 0 & 0 & 44{,}08 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1412{,}92 & 1189{,}6 & 1071{,}2 \\ 0 & 0 & 0 & 1189{,}6 & 1564{,}92 & 1127{,}34 \\ 0 & 0 & 0 & 1071{,}2 & 1127{,}34 & 1268{,}92 \end{bmatrix}$$

and

$$\operatorname{cov}(\delta)=\begin{bmatrix} 1420{,}3 & 1446{,}3 & 1372{,}3 & 1413{,}0 \\ 1446{,}3 & 1495{,}4 & 1408{,}4 & 1450{,}0 \\ 1372{,}3 & 1408{,}4 & 1347{,}4 & 1376{,}0 \\ 1413{,}0 & 1450{,}0 & 1376{,}0 & 1427{,}7 \end{bmatrix} \tag{12}$$

Connection diagram for the calibration of the F792 against the PMJTC:

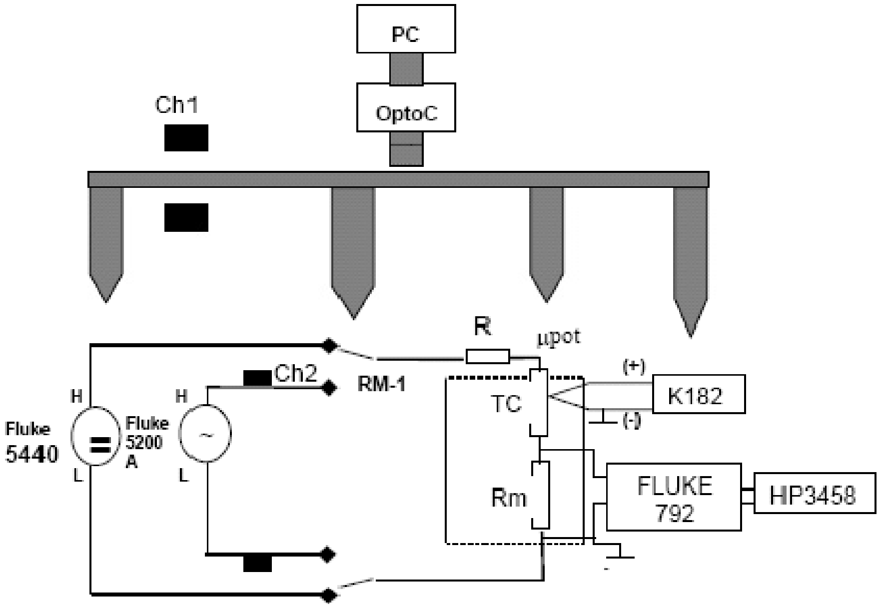


Fluke 5440B = DC Calibrator Fluke 5440B
Fluke 5200 = AC Calibrator Fluke 5200
RM-1 = Relay.
Ch1, Ch2 = Choke
F 792 = Fluke 792 Transfer (unknown)
TCn = Thermal converter (Standard)
K182 = Keithley 182 Digital Voltmeter
HP 3458 = Hewlett Packard 3458 multimeter
OptoC = Opto coupler

RD = Resistive divider

- The guards of the calibrators are externally grounded
- The digital filter of the nanovoltimeter Keithley 182 is settled to MEDIUM and the analogue filter is settled to ON.

Connection diagram for the calibration of the F792 against the micropotentiometer:



Fluke 5440B = DC calibrator Fluke 5440B

Fluke 5200 = AC calibrator Fluke 5200

RM-1 = Relays

R = Resistance

R_m = Radial resistor of µpot.

OptoC = Opto coupler

K182 = Keithley 182 Digital Voltmeter

HP 3458 = Hewlett Packard 3458 multimeter

Fluke 792 = Fluke 792 Transfer (unknown)

µpot = Micropotentiometer

- The guards of the calibrators are externally grounded
- The digital filter of the nanovoltimeter Keithley 182 is settled to MEDIUM and the analogue filter is settled to ON.

Environmental conditions of the measurement:

Temperature: (23±1)°C
Humidity: (50±3)%

Measurements Results:

Measurement point	AC-DC voltage transfer difference (δ) μV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) μV/V	Coverage factor
100 mV / 1 kHz	8,7	12,6	2
100 mV / 20 k Hz	3	13	2
100 mV / 100 kHz	19	25	2
100 mV / 1 MHz	14	75	2

The reference standard, and its traceability to de SI

See Apendix 1

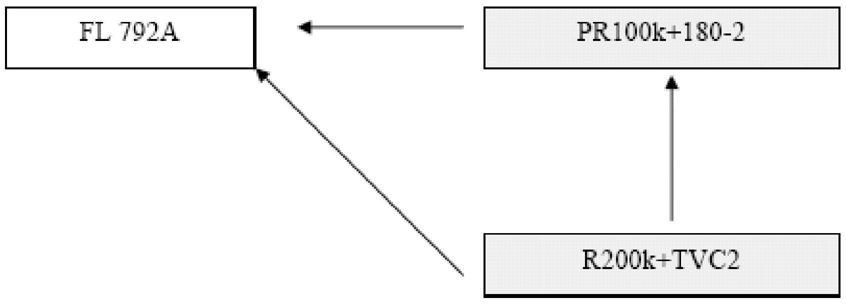
REPORT OF RESULTS
SIM.EM-K9
1000 V

Participating laboratory: INTI, Instituto Nacional de Tecnología Industrial

Date of measurements: 4th March 2004 to 16th April 2004

Description of the measuring method:

At 1000 V the travelling standard was calibrated against two Planar Multijunction Thermal Converters with two range resistors using INTI's regular set up.



These comparisons yield to the following system of equations:

$$\begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ -1 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \delta_{PR100k+180-2} \\ \delta_{R200k+TVC2} \\ \delta_{FL792} \end{bmatrix} = \begin{bmatrix} a \\ b \\ c \\ \delta_{PR100k+180-2} \\ \delta_{R200k+TVC2} \end{bmatrix} \qquad (13)$$

i.e.

$$[\mathbf{A}] \cdot [\delta] = [\mathbf{B}] \qquad (14)$$

and, using the least square method

$$\delta = (\mathbf{A}^t \cdot \mathbf{A})^{-1} \cdot \mathbf{A}^{-1} \cdot \mathbf{B} = \mathbf{C} \cdot \mathbf{B} \qquad (15)$$

According to the method described in [1] the associated uncertainties of [δ] are calculated as the square root of the diagonal terms of the covariance matrix

$$\mathrm{cov}(\delta) = \mathbf{C} \cdot \mathrm{cov}(\mathbf{B}) \cdot \mathbf{C}^t \tag{16}$$

and cov(B) is the covariance matrix of B. The diagonal terms of cov(B) are:

$$\mathrm{var}(i) = u_A^2(i) + u_C^2(i) + u_M^2(i) \qquad \mathrm{i=a,b,c} \tag{17}$$

where

$u_A(i)$ is the Type A standard uncertainty

$u_C(i)$ is the standard uncertainty of the comparison of two standards

$u_M(i)$ is the standard uncertainty of the scheme of the comparison

Table III presents the components of the covariance of B matrix at 1000 V. The correlation between the thermal converters is equal to 1.

Table III – Uncertainty components at 1000 V

	$u_A(a)$	$u_C(a)$	$u_M(a)$	$u(\delta_{R100k+180-2})$
1 kHz	0,9	0,6	2,6	7
10 kHz	0,9	0,6	5,8	8
20 kHz	0,8	0,6	6,9	15
50 kHz	1,0	0,6	7,1	17,0
100 kHz	1,1	0,6	27,0	25,0

For example, at 1 kHz we get

$$\mathrm{cov}(B) = \begin{bmatrix} 8{,}8 & 0 & 0 & 0 & 0 \\ 0 & 6{,}7 & 0 & 0 & 0 \\ 0 & 0 & 7{,}9 & 0 & 0 \\ 0 & 0 & 0 & 56{,}0 & 56{,}0 \\ 0 & 0 & 0 & 56{,}0 & 56{,}0 \end{bmatrix} \text{ and } \mathrm{cov}(\delta) = \begin{bmatrix} 56{,}8 & 55{,}2 & 55{,}9 \\ 55{,}2 & 56{,}8 & 56{,}1 \\ 55{,}9 & 56{,}1 & 59{,}7 \end{bmatrix} \tag{18}$$

At 120 V the travelling standard was calibrated against two Planar Multijunction Thermal Converters with two range resistors using INTI's regular set up.

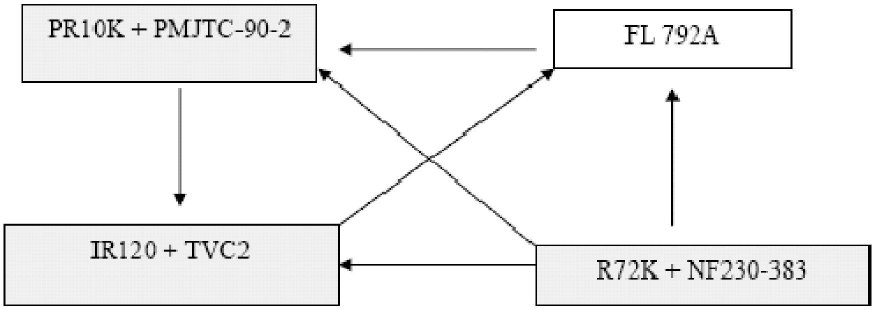


Table IV presents the components of the covariance of B matrix at 120 V. The correlation between the thermal converters is equal to 1.

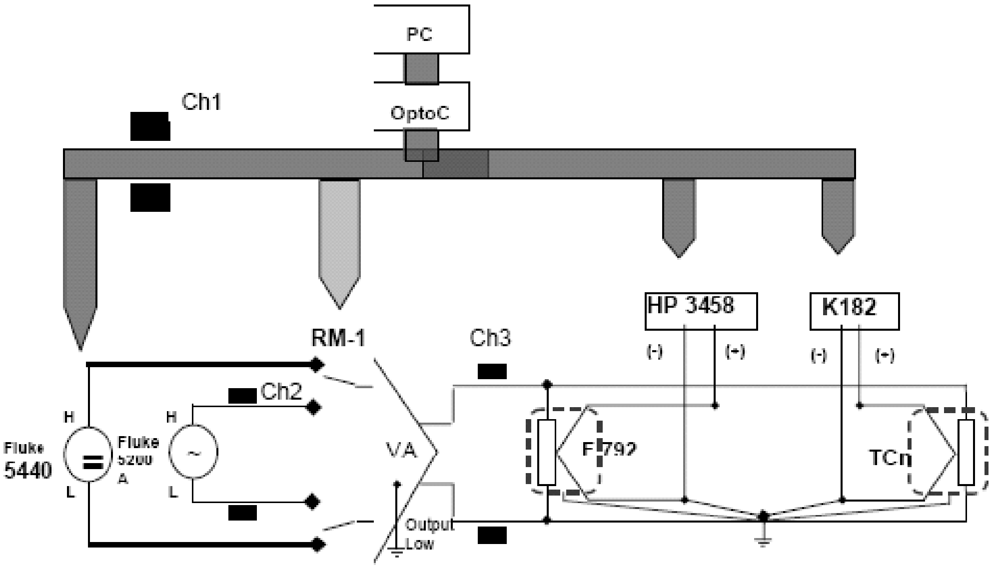
Table IV – Uncertainty components at 120 V

	$u_A(a)$	$u_C(a)$	$u_M(a)$	$u(\delta_{PR10k+1PMJTC\text{-}90\text{-}2})$
53 Hz	0,5	1,6	2,8	5

At 53 Hz we get

$$\operatorname{cov}(B)=\begin{bmatrix} 11{,}1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 11{,}1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 12{,}4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 10{,}7 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 11{,}0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 10{,}2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 35{,}1 & 35{,}1 & 30{,}3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 35{,}1 & 35{,}1 & 30{,}3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 30{,}3 & 30{,}3 & 26{,}1 \end{bmatrix} \text{ and } \operatorname{cov}(\delta)=\begin{bmatrix} 33{,}8 & 32{,}1 & 31{,}1 & 32{,}3 \\ 32{,}1 & 33{,}8 & 31{,}1 & 32{,}3 \\ 31{,}1 & 31{,}1 & 32{,}0 & 31{,}3 \\ 32{,}3 & 32{,}3 & 31{,}3 & 35{,}8 \end{bmatrix} \qquad (19)$$

Connection diagrams:



Fluke 5440B = DC Calibrator Fluke 5440B
Fluke 5200 = AC Calibrator Fluke 5200
RM-1 = Relay.
Ch2, Ch3 = Choke
F 792 = Fluke 792 Transfer (unkown)
TCn = Thermal converter (Standard)
K182 = Keithley 182 Digital Voltmeter
HP 3458 = Hewlett Packard 3458 multimeter
OptoC = Opto coupler
VA = Voltage amplifier

Environmental conditions of the measurement:

Temperature: (23±1)°C
Humidity: (50±3)%

Measurements Results:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
1000 V / 1 kHz	5,2	16	2
1000 V / 10 kHz	3,2	20	2
1000 V / 20 kHz	6,1	33	2
1000 V / 50 kHz	-1,7	37	2
1000 V / 100 kHz	10,5	74	2
120 V / 53 Hz	2,2	12	2

The reference standard, and its traceability to de SI

See Apendix 1

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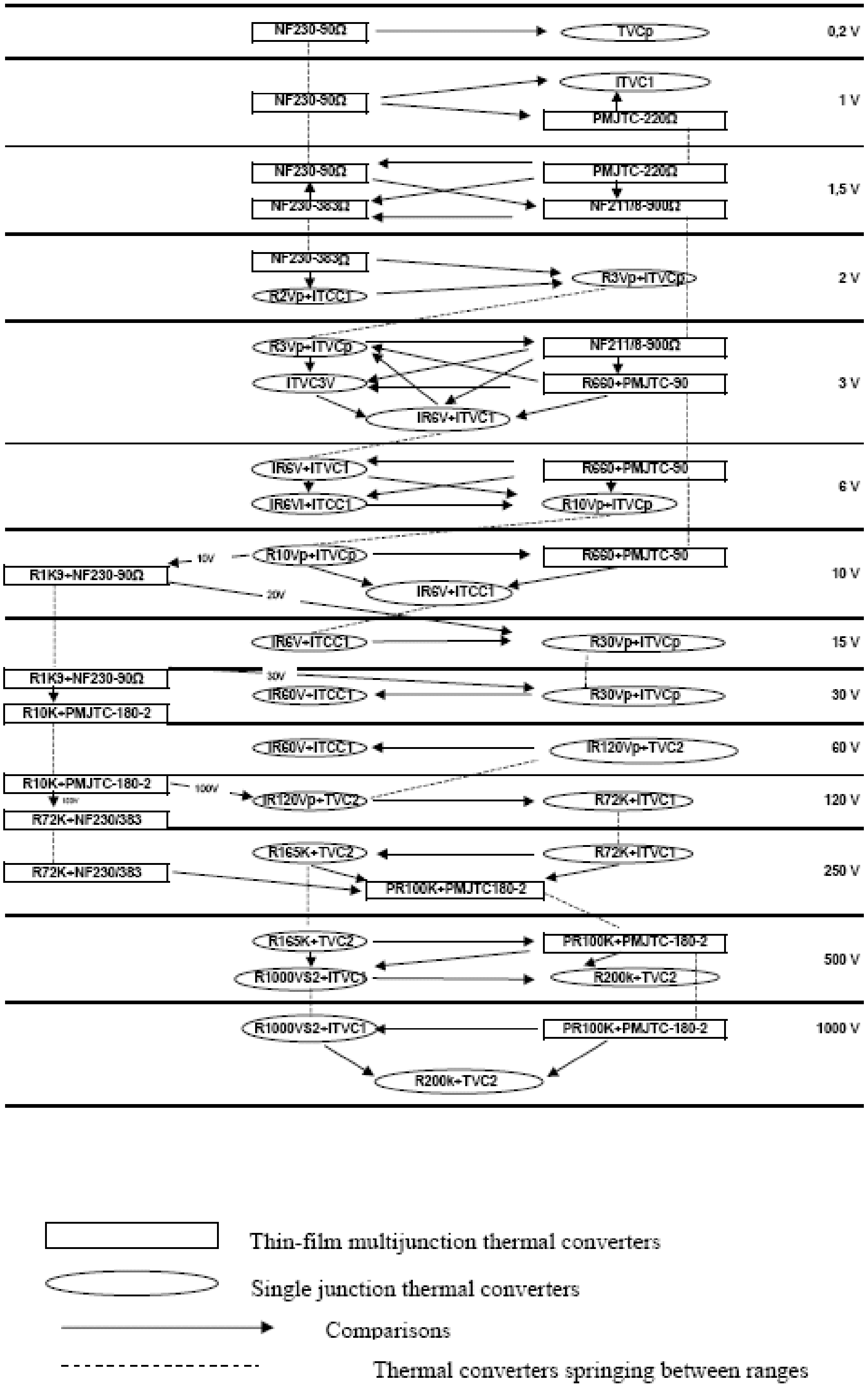
APENDIX 1

AC-DC Voltage Transfer Standards at INTI (Argentina)

1. INTRODUCTION

The AC-DC voltage transfer at INTI is based on the scheme shown in Figure 1. At 1,5 V four PTB Thin-film multijunction thermal converters (PMJTCs) [1,2], are the basis of the system. In this step-up procedure the only assumption made is that the ac-dc transfer difference of each standard remains constant along its voltage range, from the reduced voltage at which it is calibrated against the neighbouring standard to its higher rated voltage. At low frequencies, a LF-design is compensated for level independence and fulfils this requirement [3]. At higher voltages and frequencies, this assumption needs a careful analysis. The high sensitivity of the PMJTC allows big steps in the step-up calibration and many steps in-between which leads to an overdetermined system to check the validity of the assumptions used in the step-up and diminishes its uncertainty.


NF230-90Ω
TVCp
0,2 V
NF230-90Ω
ITVC1
PMJTC-220Ω
1 V
NF230-90Ω
PMJTC-220Ω
NF230-383Ω
NF211/8-900Ω
1,5 V
NF230-383Ω
R3Vp+ITVCp
R2Vp+ITCC1
2 V
R3Vp+ITVCp
NF211/8-900Ω
ITVC3V
R660+PMJTC-90
IR6V+ITVC1
3 V
IR6V+ITVC1
R660+PMJTC-90
IR6VI+ITCC1
R10Vp+ITVCp
6 V
10V
R10Vp+ITVCp
R660+PMJTC-90
R1K9+NF230-90Ω
IR6V+ITCC1
20V
10 V
IR6V+ITCC1
R30Vp+ITVCp
15 V
R1K9+NF230-90Ω
30V
R10K+PMJTC-180-2
IR60V+ITCC1
R30Vp+ITVCp
30 V
IR60V+ITCC1
IR120Vp+TVC2
60 V
R10K+PMJTC-180-2
100V
IR120Vp+TVC2
R72K+ITVC1
100V
R72K+NF230/383
120 V
R165K+TVC2
R72K+ITVC1
R72K+NF230/383
PR100K+PMJTC180-2
250 V
R165K+TVC2
PR100K+PMJTC-180-2
R1000VS2+ITVC1
R200k+TVC2
500 V
R1000VS2+ITVC1
PR100K+PMJTC-180-2
R200k+TVC2
1000 V
Thin-film multijunction thermal converters
Single junction thermal converters
Comparisons
Thermal converters springing between ranges

2. STEP-UP PROCESS

a. Voltages up to 250 V

At each other voltage level the same idea as at 1,5 V is used. At frequencies below 100 Hz, the thermal converters are calibrated against the improved LF-PMJTC with appropriate range resistors. For higher frequencies a system is built in which the same converters are compared and more than one of them which were calibrated at a lower voltage are taken as reference. Using the least squares method the values for the new converters are assigned. For instance, at 6 V we get (see the comparison scheme in Figure 1).

$$\begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & 1 & -1 \\ -1 & 0 & 0 & 1 \\ -1 & 0 & 1 & 0 \\ 0 & -1 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \delta_{IR6V+ITVC1} \\ \delta_{R660+PMJTC-90} \\ \delta_{R10Vp+ITVCp} \\ \delta_{IR6VT+ITCC1} \end{bmatrix} = \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ \delta_{IR6V+ITVC1-LV} \\ \delta_{R660+PMJTC-90-LV} \end{bmatrix} \tag{3.1}$$

where $a,b,c,d,e,$ and f are the results of the comparisons and $\delta_{\ldots\text{-LV}}$ are the values obtained for these thermal converters at lower voltages.

b. U ≥ 250 V

A planar thin-film resistor of 100 kΩ together with a PMJTC with R_H=180 Ω is used as standard up to 1000 V. It is calibrated at 250 V and no voltage dependence is assumed. A study of the influence of the shield in the voltage dependence was carried out, in order to checkout this hypothesis [4]. Two other standards, R1000Vs2+ITVC1 and R200k+TVC2, are used to calculate the comparisons uncertainty at these voltage levels, according to the method described above.

REFERENCES

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Incertidumbre del 792 en 100mV (Rango 220mV) 1kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	ν_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.000000000	6.10E-07	n	1.0	15	6.10E-07	3.72E-13	9.23056E-27
Incertidumbre mpot	δ_{mpot}	1.000000000	5.90E-06	n	1.0	50	5.90E-06	3.48E-11	2.42347E-23
Coef n del mpot	δ_{ss}	0.00001315	8.34E-06	n	2.0	50	5.49E-11	3.01E-21	1.8103E-43
Sistema de medición	δ_{3458}	1.000000000	1.50E-06	n	1.0	2	1.50E-06	2.25E-12	2.53125E-24
Estabilidad de 3458	δ_{182}	0.000055631	3.90E-07	r	1.7	50	1.28E-11	1.63E-22	5.29936E-46
Estabilidad del 182	δ_{M}	0.000417063	2.13E-07	r	1.7	50	5.22E-11	2.73E-21	1.48994E-43
Diferencia AC-DC debida al conexionado	δ_{conect}	1.000000000	2.00E-06	r	1.7	50	1.18E-06	1.38E-12	3.83137E-26
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.000000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		56	6.24E-06	3.89E-11	
Incertidumbre Expandida				**N (95%)**	2.0		**1.25E-05**		

Incertidumbre del 792 en 100mV (Rango 220mV) 20 kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribucio	Factor	ν_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.000000000	3.80E-07	n	1.0	15	3.80E-07	1.44E-13	1.39009E-27
Incertidumbre mpot	δ_{mpot}	1.000000000	6.10E-06	n	1.0	50	6.10E-06	3.72E-11	2.76917E-23
Coef n del mpot	δ_{ss}	0.00001315	8.63E-06	n	2.0	50	5.67E-11	3.22E-21	2.06853E-43
Sistema de medición	δ_{3458}	1.000000000	1.10E-06	n	1.0	2	1.10E-06	1.21E-12	7.3205E-25
Estabilidad de 3458	δ_{182}	0.000055632	3.90E-07	r	1.7	50	1.28E-11	1.63E-22	5.29959E-46
Estabilidad del 182	δ_{M}	0.000417279	2.13E-07	r	1.7	50	5.23E-11	2.73E-21	1.49123E-43
Diferencia AC-DC debida al conexionado	δ_{conect}	1.000000000	2.00E-06	r	1.7	50	1.18E-06	1.38E-12	3.83137E-26
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.000000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		56	6.33E-06	4.00E-11	
Incertidumbre Expandida				**N (95%)**	2.0		1.27E-05		

Incertidumbre del 792 en 100mV (Rango 220mV) 100kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	ν_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.0000000	3.70E-07	n	1.0	15	3.70E-07	1.37E-13	1.24944E-27
Incertidumbre mpot	δ_{mpot}	1.0000000	1.20E-05	n	1.0	50	1.20E-05	1.44E-10	4.1472E-22
Coef n del mpot	δ_{ss}	0.00001315	1.70E-05	n	2.0	50	1.12E-10	1.24E-20	3.09789E-42
Estabilidad de 3458	δ_{3458}	0.000055637	3.90E-07	r	1.7	50	1.28E-11	1.63E-22	5.30086E-46
Sistema de medición	δ_{182}	1.000000000	2.30E-06	n	1.0	2	2.30E-06	5.29E-12	1.39921E-23
Estabilidad del 182	δ_{M}	0.000417360	2.13E-07	r	1.7	50	5.23E-11	2.73E-21	1.49172E-43
Diferencia AC-DC debida al conexionado	δ_{conect}	1.0000000	4.00E-06	r	1.7	50	2.35E-06	5.54E-12	6.13019E-25
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.0000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		56	1.25E-05	1.55E-10	
Incertidumbre Expandida				**N (95%)**	2.0		**2.50E-05**		

Incertidumbre del 792 en 100mV (Rango 220mV) 1MHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	ν_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.00000000	4.00E-07	n	1.0	15	4.00E-07	1.60E-13	1.70667E-27
Incertidumbre mpot	δ_{mpot}	1.00000000	3.65E-05	n	1.0	50	3.65E-05	1.33E-09	3.54978E-20
Coeficiente n del mpot	δ_{ss}	0.00001315	5.16E-05	n	2.0	50	3.39E-10	1.15E-19	2.65163E-40
Estabilidad de 3458	δ_{3458}	0.000055635	3.90E-07	r	1.7	50	1.28E-11	1.63E-22	5.29971E-46
Estabilidad del 182	-δ_{182}	0.000417488	2.13E-07	r	1.7	50	5.23E-11	2.73E-21	1.4925E-43
Sistema de medición	δ_{M}	1.000000000	2.80E-06	n	1.0	2	2.80E-06	7.84E-12	3.07328E-23
Diferencia AC-DC debida al conexionado	δ_{conect}	1.00000000	1.00E-05	r	1.7	50	5.88E-06	3.46E-11	2.39461E-23
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.00000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinad a				**N (1s)**		53	3.71E-05	1.37E-09	
Incertidumbre Expandida				**N (95%)**	2.0		**7.44E-05**		

Incertidumbre del 792 en 1000V (Rango 1000 V) 1kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	ν_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.000000000	9.30E-07	n	1.0	15	9.30E-07	8.65E-13	4.98701E-26
Incertidumbre PRI 100k+180-2	δ_{R}	1.000000000	7.00E-06	n	1.0	50	7.00E-06	4.90E-11	4.802E-23
Estabilidad de 3458	δ_{3458}	0.000029210	4.71E-07	r	1.7	50	8.10E-12	6.55E-23	8.59199E-47
Estabilidad del 182	δ_{182}	0.000155473	4.12E-07	r	1.7	50	3.76E-11	1.42E-21	4.0156E-44
sistema de medición	δ_{M}	1.000000000	3.00E-06	n	1.0	2	3.00E-06	9.00E-12	4.05E-23
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.000000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		39	7.68E-06	5.90E-11	
Incertidumbre Expandida				**N (95%)**	2.0		**1.55E-05**		

Incertidumbre del 792 en 1000V (Rango 1000 V) 10 kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	v_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.00000000	8.00E-07	n	1.0	15	8.00E-07	6.40E-13	2.73067E-26
Incertidumbre PR100k+180-2	δ_R	1.00000000	8.00E-06	n	1.0	50	8.00E-06	6.40E-11	8.192E-23
Estabilidad de 3458	δ_{3458}	0.000029209	4.71E-07	r	1.7	50	8.10E-12	6.55E-23	8.59087E-47
Estabilidad del 182	δ_{182}	0.000156025	4.10E-07	r	1.7	50	3.77E-11	1.42E-21	4.02811E-44
sistema de medicion	δ_M	1.00000000	5.60E-06	n	1.0	2	5.60E-06	3.14E-11	4.91726E-22
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.00000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		16	9.80E-06	9.61E-11	
Incertidumbre Expandida				**N (95%)**	2.1		**2.08E-05**		

Incertidumbre del 792 en 1000V (Rango 1000 V) 20 kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	v_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.000000000	8.50E-07	n	1.0	15	8.50E-07	7.23E-13	3.48004E-26
Incertidumbre PR100k+180-2	δ_R	1.000000000	1.50E-05	n	1.0	50	1.50E-05	2.25E-10	1.0125E-21
Estabilidad de 3458	δ_{3458}	0.000029202	4.71E-07	r	1.7	50	8.09E-12	6.55E-23	8.58568E-47
Estabilidad del 182	δ_{182}	0.000156124	4.10E-07	r	1.7	50	3.77E-11	1.42E-21	4.03085E-44
sistema de medición	δ_M	1.000000000	7.00E-06	n	1.0	2	7.00E-06	4.90E-11	1.2005E-21
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.000000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49661E-28
Incertidumbre Combinada				**N (1s)**		24	1.66E-05	2.75E-10	
Incertidumbre Expandida				**N (95%)**	2.0		**3.37E-05**		

Incertidumbre del 792 en 1000V (Rango 1000 V) 50 kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	v_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.0000000	9.70E-07	n	1.0	15	9.70E-07	9.41E-13	5.90195E-26
Incertidumbre PR100k+180-2	δ_R	1.0000000	1.60E-05	n	1.0	50	1.60E-05	2.56E-10	1.31072E-21
Estabilidad de 3458	δ_{3458}	0.000029207	4.71E-07	r	1.7	50	8.10E-12	6.55E-23	8.58925E-47
Estabilidad del 182	δ_{182}	0.000156222	4.10E-07	r	1.7	50	3.77E-11	1.42E-21	4.03255E-44
sistema de medición	δ_M	1.00000000	8.00E-06	n	1.0	2	8.00E-06	6.40E-11	2.048E-21
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.0000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		31	1.79E-05	3.21E-10	
Incertidumbre Expandida				**N (95%)**	2.0		**3.66E-05**		

Incertidumbre del 792 en 1000V (Rango 1000 V) 100 kHz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribución	Factor	v_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.00000000	1.10E-06	n	1.0	15	1.10E-06	1.21E-12	9.76067E-26
Incertidumbre PR100k+180-2	δ_R	1.00000000	2.70E-05	n	1.0	50	2.70E-05	7.29E-10	1.06288E-20
Estabilidad de 3458	δ_{3458}	0.000029207	4.71E-07	r	1.7	50	8.09E-12	6.55E-23	8.58793E-47
Estabilidad del 182	δ_{182}	0.000156182	4.10E-07	r	1.7	50	3.77E-11	1.42E-21	4.03161E-44
sistema de medición	δ_M	1.000000000	2.10E-05	n	1.0	2	2.10E-05	4.41E-10	9.72405E-20
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.00000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		13	3.42E-05	1.17E-09	
Incertidumbre Expandida				**N (95%)**	2.2		**7.46E-05**		

Incertidumbre del 792 en 120V 53 Hz

Fuente de incertidumbre	Simbolo	c_i	Valor (±)	Distribucion	Factor	v_i	u_i	u_i^2	W-S
Desviacion standard de las mediciones	δ_A	1.00000000	5.00E-06	n	1.0	15	5.00E-06	2.50E-11	4.16667E-23
Incertidumbre PR100k+180-2	δ_R	1.00000000	2.60E-06	n	1.0	50	2.60E-06	6.76E-12	9.13952E-25
Estabilidad de 3458	δ_{3458}	0.000029207	4.71E-07	r	1.7	50	8.09E-12	6.55E-23	8.58793E-47
Estabilidad del 182	δ_{182}	0.000156182	4.10E-07	r	1.7	50	3.77E-11	1.42E-21	4.03161E-44
sistema de medición	δ_M	1.00000000	2.50E-06	n	1.0	2	2.50E-06	6.25E-12	1.95313E-23
Diferencia AC-DC debida al coef. de temp del 792	δ_{TE}	1.00000000	5.00E-07	r	1.7	50	2.94E-07	8.65E-14	1.49663E-28
Incertidumbre Combinada				**N (1s)**		23	6.17E-06	3.81E-11	
Incertidumbre Expandida				**N (95%)**	2.1		**1.28E-05**		

REPORT OF RESULTS
SIM.EM-K6a.

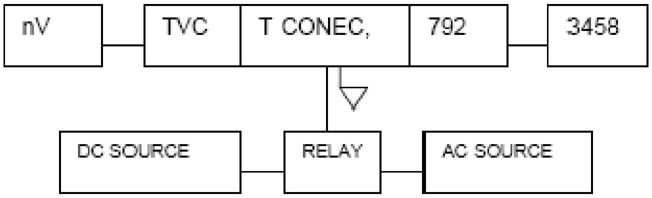
Participating laboratory: __UTE (Uruguay)___________________________

Date of measurements: ____18/05/2004 – 22/06/2004___________________________

Description of the measuring method:

Measuring with 2 channels (nanovoltmeter and voltmeter) and switching with relay

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation

23°C ± 1°C, 45% ± 10%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
3 V / 1 kHz	3	5.5	1
3 V / 20 k Hz	6	5.4	1
3 V / 100 kHz	18	9.5	1
3 V / 1 MHz	3	30	1

The reference standard, and its traceability to de SI

TVC THTR LABUTE (SJTC) 1 V, MODEL TUB, N° 55288/004

3 V RANGE RESISTOR LABUTE, MODEL TUB, N° 55288/005

TRACEABILITY TO PTB (GERMANY)

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the ISO Guide to the Expression of Uncertainty in Measurements 1995 .(All participating laboratories must fill the following table with its own uncertainty contribution, specific for their own measurements system)

SIM.EM-K6a (3 V)

Uncertainty component	Estimate x_i				Relative standard uncertainty $u(x_i)$				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				uncertainty contribution $u(\delta)$				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																								
• Reference Standard calibration	4	6	28	170	4.2	4.1	8.8	30	N/B	N/B	N/B	N/B	-1	-1	-1	-1	-4.2	-4.1	-8.8	-30				
• Reference standard stability	0	0	0	0	1.5	1.1	1.8		A	A	A		-1	-1	-1		-1.5	-1.1	-1.8		3	3	3	
•																								
•																								
Difference measurement:																								
• Standard deviation of measurements	-1	0	-10	-167	0.9	0.9	0.5	1.8	A	A	A	A	1	1	1	1	0.9	0.9	0.5	1.8	10	8	9	4
• Nanovoltmeters short time stability																								
• Measurement set up	0	0	0	0	3.0	3.0	3.0	3.0	N/B	N/B	N/B	N/B	1	1	1	1	3.0	3.0	3.0	3.0				
• Tee connector	0	0	0	0	1.0	1.0	1.0	2.0	B	B	B	B	1	1	1	1	1.0	1.0	1.0	2.0				
•																								
•																								
δ	3	6	18	3																ν_{eff}				

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K11

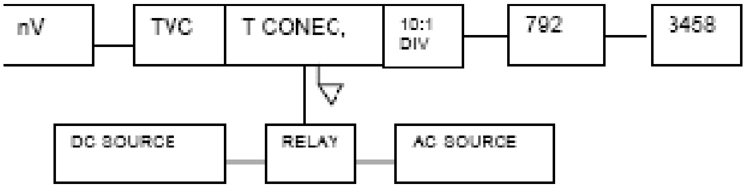
Participating laboratory: ____UTE (Uruguay)________________________

Date of measurements: _____18/05/2004 – 22/06/2004_________________

Description of the measuring method:

Measuring with 2 channels (nanovoltmeter and voltmeter) and switching with relay

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation

23°C ± 1°C, 45% ± 10%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
100 mV / 1 kHz	14	7.5	1
100 mV / 20 k Hz	-2	7.7	1
100 mV / 100 kHz	18	18	1
100 mV / 1 MHz	26	52	1

The reference standard, and its traceability to de SI

TVC THTR LABUTE (SJTC) 1 V, MODEL TUB, N° 55288/004

10:1 RESISTIVE DIVIDER LABUTE, MODEL TUB, N° 55288/052

TRACEABILITY TO PTB (GERMANY)

SIM.EM-K11 (100 mV)																												
Uncertainty component	Estimate x_i				Relative standard unceraínty $u(x_i)$				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				uncertainty contribution $u_i(\delta)$				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																								
• Reference Standard calibration	5	10	44	216	6.8	7.0	18	52	N/B	N/B	N/B	N/B	-1	-1	-1	-1	-6.8	-7.0	-18	-52				
• Reference standard stability																								
•																								
•																								
Difference measurement																								
• Standard deviation of measurements	9	-12	-26	-190	0.8	0.7	2.2	4.2	A	A	A	A	1	1	1	1	0.8	0.7	2.2	4.2	14	15	17	14
• Nanovoltmeters short time stability																								
• Measurement set up	0	0	0	0	3.0	3.0	3.0	3.0	N/B	N/B	N/B	N/B	1	1	1	1	3.0	3.0	3.0	3.0				
• Tee connector	0	0	0	0	1.0	1.0	2.0	4.0	B	B	B	B	1	1	1	1	1.0	1.0	2.0	4.0				
•																								
•																								
δ	14	-2	18	26													ν_{eff}							

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K9

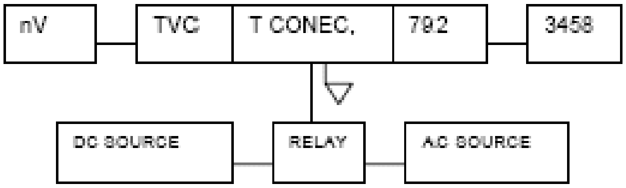
Participating laboratory: _____ UTE (Uruguay)____________

Date of measurements: ______18/05/2004 – 22/06/2004______

Description of the measuring method:

Measuring with 2 channels (nanovoltmeter and voltmeter) and switching with relay

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation

23°C ± 1°C, 45% ± 10%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
1000 V / 1 kHz	4	11	1
1000 V / 10 kHz	10	12	1
1000 V / 20 kHz	11	11	1
1000 V / 50 kHz			
1000 V / 100 kHz			
120 V / 53 Hz	2	7.0	1

The reference standard, and its traceability to de SI

TVC THTR LABUTE (SJTC) 1 V, MODEL TUB, N° 55288/004

100 V RANGE RESISTOR LABUTE, MODEL TUB, N° 55288/008

1000 V RANGE RESISTOR LABUTE, MODEL TUB, N° 55288/016.

TRACEABILITY TO PTB (GERMANY)

SIM.EM-K9 (1000 V)

Uncertainty component	Estimate x_i					Relative standard uncertainty $u(x_i)$					Probability Distribution / Method of evaluation (A, B)					Sensitivity coefficient c_i					uncertainty contribution $u_i(\delta)$					Degree of freedom ν_i				
Frequencies (kHz)	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100
Reference Standard:																														
• Reference Standard calibration	1	13	17			10	11	9.9			N/B	N/B	N/B			-1	-1	-1			-10	-11	-9.9							
• Reference standard stability																														
•																														
•																														
Difference measurement:																														
• Standard deviation of measurements	3	-3	-6			1.6	1.3	1.8			A	A	A			1	1	1			1.6	1.3	1.8			5	5	5		
• Nanovoltmeters short time stability																														
• Measurement set up	0	0	0			3.0	3.0	3.0			N/B	N/B	N/B			1	1	1			3.0	3.0	3.0							
• Tee connector	0	0	0			1.0	1.0	2.0			B	B	B			1	1	1			1.0	1.0	2.0							
•																														
•																														
δ	4	10	11																						ν_{eff}					

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K11

Participating laboratory: __Inmetro____________________

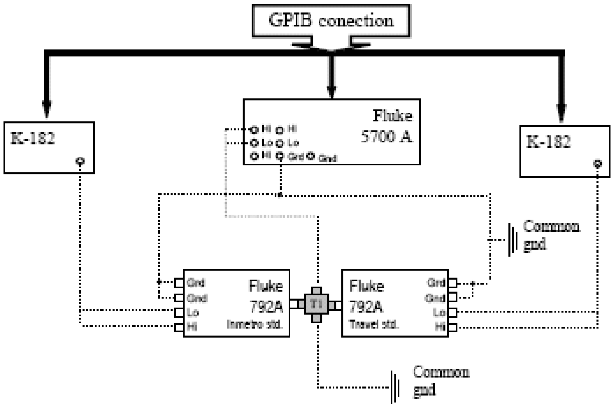
Date of measurements: __28/june to 28/july/2004__________

Description of the measuring method:

Direct comparison with Inmetro´s transfer standard Fluke 792A (serial number 6635003) An ac and dc source Fluke 5700A (serial number 6625602) was used to derive the voltage signals to both standards using a "T" connector type N.

Connection diagrams:

System 1 voltage: 100 mV
frequency: from 1kHz up to 1 MHz;



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (22,5 ± 1,0)°C

Humidity: (55 ± 5)%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
100 mV / 1 kHz	8	8	2,02
100 mV / 20 kHz	-2	8	2,02
100 mV / 100 kHz	18	13	2,02
100 mV / 1 MHz	79	98	2,05

The reference standard, and its traceability to de SI

Fluke 792A (serial number 6635003) traceable to PTB with calibration certificate number 3000/3009PTD01 issued in 2002.

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the ISO Guide to the Expression of Uncertainty in Measurements 1995 .(All participating laboratories must fill the following table with its own uncertainty contribution, specific for their own measurements system)

Distribution: N – normal T – triangular R – rectangular

SIM.EM-K11 (100 mV)

Uncertainty component	Estimate x_i (μV)				Relative standard uncertainty $u(x_i)$ (μV)				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				uncertainty contribution $u_i(\delta)$ (μV)				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																								
• Reference Standard calibration	2	-15	16	1383	3	3	5	50	N/B	N/B	N/B	N/B	1	1	1	1	3	3	5	50	50	50	50	50
• Reference standard n coefficient	0	0	0	0	5	5	5	5	R/B	R/B	R/B	R/B	5,5e-6	5,5e-6	5,5e-6	5,5e-6	16e-6	16e-6	16e-6	16e-6	50	50	50	50
• Reference standard ac/dc temperature differ.	0	0	0	0	0,5	0,5	0,5	0,5	R/B	R/B	R/B	R/B	1	1	1	1	0,29	0,29	0,29	0,29	50	50	50	50
•																								
Difference measurement:																								
• Standard deviation of measurements	6	13	2	-1304	3	1	2	1	N/A	N/A	N/A	N/A	1	1	1	1	0,80	0,27	0,53	0,27	14	14	14	14
• Nanovoltmeters short time stability	0	0	0	0	70	70	70	70	R/B	R/B	R/B	R/B	5,5e-6	5,5e-6	5,5e-6	5,5e-6	2,2e-4	2,2e-4	2,2e-4	2,2e-4	50	50	50	50
• Measurement set up	0	0	0	0	3	3	3	3	R/B	R/B	R/B	R/B	1	1	1	1	1,50	1,50	1,50	1,50	50	50	50	50
• Tee connector	0	0	0	0	4	4	7	7	R/B	R/B	R/B	R/B	1	1	1	1	2,3	2,3	4,0	4,0	50	50	50	50
•																								
•																								
δ																				ν_{eff}	143	135	108	51

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K6a.

Participating laboratory: __Inmetro______________________

Date of measurements: __28/june to 28/july/2004___________

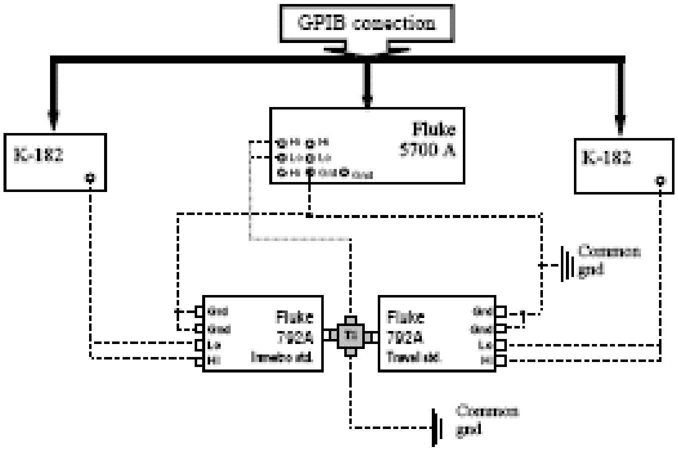
Description of the measuring method:

Direct comparison with Inmetro´s transfer standard Fluke 792A model (serial number 6635003).

An ac and dc source Fluke 5700A (serial number 6625602) was used to derive the voltage signals to both standards using a "T" connector type N.

Connection diagrams:

System 1 voltage: 3 V – frequency: from 1kHz up to 1 MHz.



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (22,5 ± 1,0)°C

Humidity: (55 ± 5)%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
3 V / 1 kHz	1	4	2,02
3 V / 20 kHz	4	4	2,02
3 V / 100 kHz	13	5	2,02
3 V / 1 MHz	- 22	32	2,04

The reference standard, and its traceability to de SI

Fluke 792A (serial number 6635003) traceable to PTB with calibration certificate number 3088/3089PTB01 issued in 2002.

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the ISO Guide to the Expression of Uncertainty in Measurements 1995 .(All participating laboratories must fill the following table with its own uncertainty contribution, specific for their own measurements system)

SIM.EM-K6a (3 V)

Uncertainty component	Estimate x_i (μV/V)				Relative standard uncertainty $u(x_i)$ (μV/V)				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				uncertainty contribution $u_i(\delta)$ (μV/V)				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																								
• Reference Standard calibration	1	6	12	-29	1	1	1	15	N/B	N/B	N/B	N/B	1	1	1	1	1	1	1	15	50	50	50	50
• Reference standard n coefficient	0	0	0	0	5	5	5	5	R/B	R/B	R/B	R/B	1,7e-4	1,7e-4	1,7e-4	1,7e-4	5e-4	5e-4	5e-4	5e-4	50	50	50	50
• Reference standard ac/dc temperature differ.	0	0	0	0	0,5	0,5	0,5	0,5	R/B	R/B	R/B	R/B	1	1	1	1	0,29	0,29	0,29	0,29	50	50	50	50
•																								
Difference measurement:																								
• Standard deviation of measurements	0	-2	1	7	1	1	2	1	N/A	N/A	N/A	N/A	1	1	1	1	0,27	0,26	0,53	0,26	14	14	14	14
• Nanovoltmeters short time stability	0	0	0	0	71	71	71	71	R/B	R/B	R/B	R/B	1,7e-4	1,7e-4	1,7e-4	1,7e-4	7e-3	7e-3	7e-3	7e-3	50	50	50	50
• Measurement set up	0	0	0	0	3	3	3	3	R/B	R/B	R/B	R/B	1	1	1	1	1,5	1,5	1,5	1,5	50	50	50	50
• Tee connector	0	0	0	0	1	1	3	7	R/B	R/B	R/B	R/B	1	1	1	1	0,6	0,6	1,7	4,0	50	50	50	50
•																								
•																								
δ																				ν_{eff}	113	112	143	58

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
Supplementary point

Participating laboratory: __Inmetro________________________

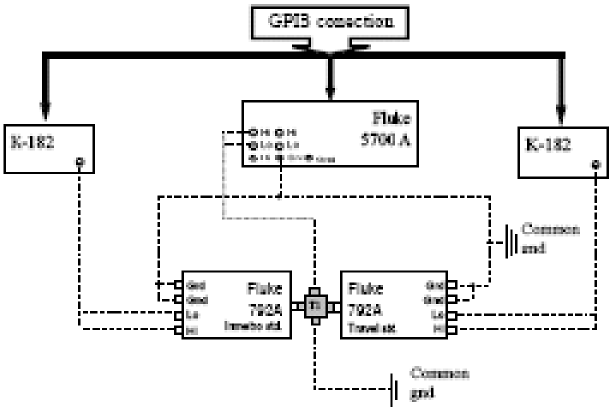
Date of measurements: __23/june to 28/july/2004_____________

Description of the measuring method:

Direct comparison with Inmetro´s transfer standard Fluke 792A (serial number 6635003) traceable to PTB with calibration certificate number 3088/3089PTB01 issued in 2002. An ac and dc source Fluke 5700A (serial number 6625602) was used to derive the voltage signals to both standards using a "T" connector type N.

Connection diagrams:

System 1 voltage: 120 V - frequency: 53 Hz.



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (22,5 ± 1,0)°C

Humidity: (55 ± 5)%

Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V	Uncertainty of the AC DC voltage transfer difference (U_δ) µV/V	Coverage factor
120 V / 53 Hz	3	14	2,02

The reference standard, and its traceability to de SI

Fluke 792A (serial number 6535003) traceable to PTB with calibration certificate number 3088/3089PTB01 issued in 2002.

A detailed uncertainty budget, the uncertainty calculation must comply with the requirements of the ISO Guide to the Expression of Uncertainty in Measurements 1995 .(All participating laboratories must fill the following table with its own uncertainty contribution, specific for their own measurements system)

Supplementary point (120 V)						
Uncertainty component	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability Distribution / Method of evaluation (A, B)	Sensitivity coefficient c_i	uncertainty contribution $u_i(\delta)$	Degree of freedom ν_i
Frequencies (Hz)	53	53	53	53	53	53
Reference Standard:						
• Reference Standard calibration	3	12	N/B	1	6,38	50
• Reference standard n coefficient	0	5	R/B	5,8e-3	0,02	50
• Reference standard ac/dc temperature differ.	0	0,5	R/B	1	0,29	50
•						
Difference measurement:						
• Standard deviation of measurements	0	1	N/A	1	0,27	14
• Nanovoltmeters short time stability	0	70,9	R/B	5,81e-3	0,24	50
• Measurement set up	0	3	R/B	1	1,5	50
• Tee connector	0	7	R/B	1	4,04	50
•						
•						
δ					ν_{eff}	

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K9

Participating laboratory: __Inmetro____________________

Date of measurements: __28/june to 28/july/2004__________

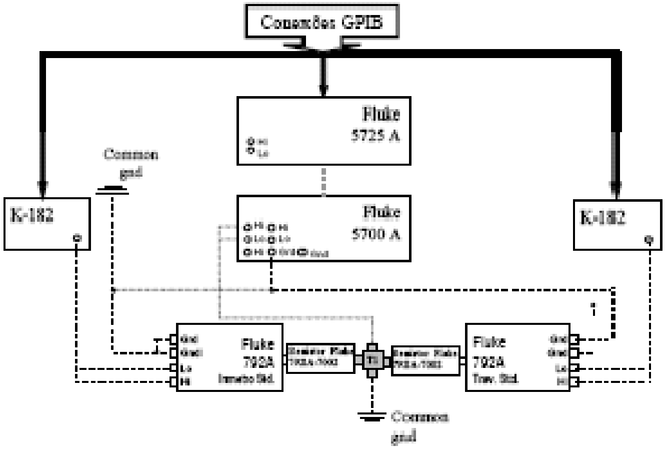
Description of the measuring method:

Direct comparison with Inmetro´s transfer standard Fluke 792A (serial number 6635003). An ac and dc source Fluke 5700A (serial number 6625602) was used to derive the voltage signals to both standards using a "T" connector type N. A 1000V Range Fluke resistor was used in the 1000 volts measurements.

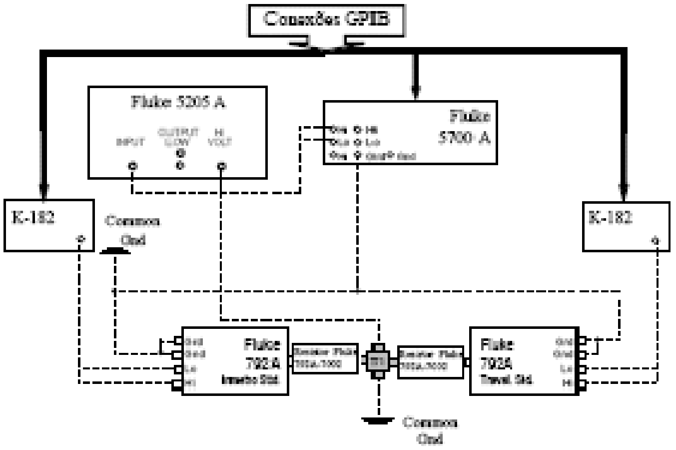
Connection diagrams:

System 1 voltage: 1000 V – frequency: from 1kHz and 10 kHz.
System 2 voltage: 1000 V – frequency: from 20kHz up to 100 kHz.

System 1



<u>System 2</u>



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (22,5 ± 1,0) °C

Humidity: (55 ± 5)%

Measurement point	AC-DC voltage transfer difference (δ) μV/V	Uncertainty of the AC-DC voltage transfer difference ($U_δ$) μV/V	Coverage factor
1000 V / 1 kHz	5	18	2,03
1000 V / 10 kHz	0	18	2,03
1000 V / 20 kHz	- 2	18	2,03
1000 V / 50 kHz	- 9	18	2,03
1000 V / 100 kHz	- 25	42	2,05

The reference standard, and its traceability to de SI

Fluke 792A (serial number 6635003) traceable to PTB with calibration certificate number 3088/3089PTB01 issued in 2002.

SIM.EM-K9 (1000 V)																														
Uncertainty component	Estimate x_i					Relative standard uncertainty $u(x_i)$					Probability Distribution / Method of evaluation (A, B)					Sensitivity coefficient c_i					uncertainty contribution $u_i(\delta)$					Degree of freedom ν_i				
Frequencies (kHz)	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100
Reference Standard:																														
• Reference Standard calibration	6	3	4	-1	-21	15	15	15	15	40	N/B	N/B	N/B	N/B	N/B	1	1	1	1	1	7,5	7,5	7,5	7,5	20	50	50	50	50	50
• Reference standard n coefficient	0	0	0	0	0	5	5	5	5	5	R/B	R/B	R/B	R/B	R/B	3e-2	3e-2	3e-2	3e-2	3e-2	0,08	0,08	0,08	0,08	0,08	50	50	50	50	50
• Reference standard ac/dc temperature differ.	0	0	0	0	0	0,5	0,5	0,5	0,5	0,5	R/B	R/B	R/B	R/B	R/B	1	1	1	1	1	0,29	0,29	0,29	0,29	0,29	50	50	50	50	50
•																														
Difference measurement:																														
• Standard deviation of measurements	-1	-3	-6	-8	-4	0	0	1	1	1	N/A	N/A	N/A	N/A	N/A	1	1	1	1	1	0	0	0,26	0,27	0,27	14	14	14	14	14
• Nanovoltmeters short time stability	0	0	0	0	0	60,5	60,5	60,5	60,5	60,5	R/B	R/B	R/B	R/B	R/B	2,9e-2	2,9e-2	2,9e-2	2,9e-2	2,9e-2	1,02	1,02	1,02	1,02	1,02	50	50	50	50	50
• Measurement set up	0	0	0	0	0	3	3	3	3	3	R/B	R/B	R/B	R/B	R/B	1	1	1	1	1	1,5	1,5	1,5	1,5	1,5	50	50	50	50	50
• Tee connector	0	0	0	0	0	7	7	7	7	7	R/B	R/B	R/B	R/B	R/B	1	1	1	1	1	4	4	4	4	4	50	50	50	50	50
•																														
•																														
δ																									ν_{eff}	86	86	86	86	55

Participating laboratories are required to include also the uncertainty budget of the calibration of its standard in order to evaluate the correlation term in case of two laboratories have traceability to a common national laboratory.

REPORT OF RESULTS
SIM.EM-K6a.

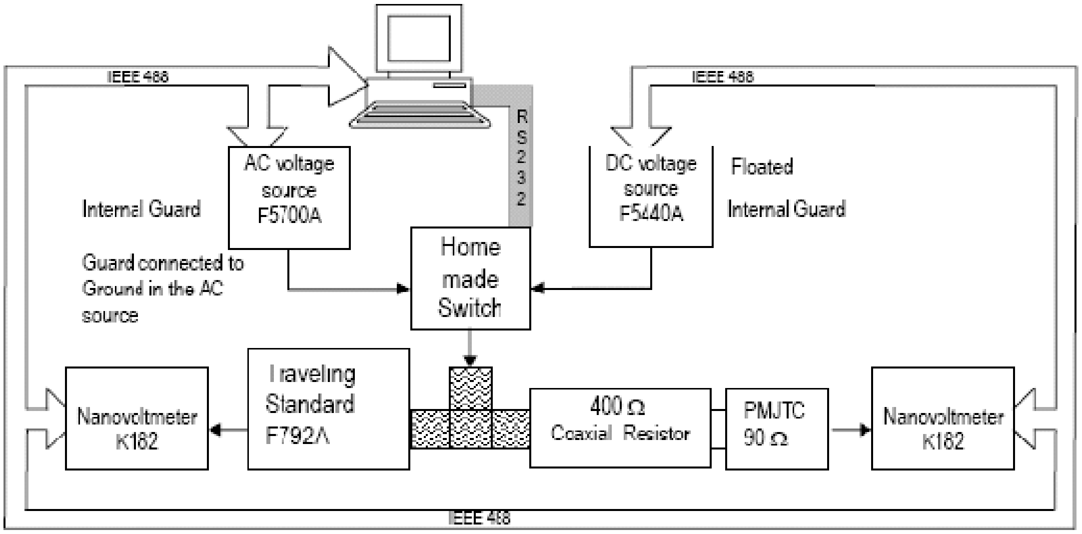
Participating laboratory: Centro Nacional de Metrologia, México
Date of measurements: 5th December to 8th December 2003
3rd and 20th August 2004
5th and 8th November 2004

Description of the measuring method:

The two channel method was used to calibrate the traveling standard against a reference thermal voltage converter, using nanovoltmeters to measure the thermal converters output. The plan of reference was the center of a type N tee connector. Two voltage sources were used to apply the AC and the DC voltage to the thermal converters using an external fast response switch. To minimize the thermal drift the sequence AC, DC+, AC, DC- AC was executed allowing AC-DC stabilization time of 90 seconds. The measurement system ran automatically.

During the measurements the DC and the AC voltage sources were configured with internal guard, the DC voltage source was floated and in the AC source guard and ground terminals were connected together.

Connection diagram



Environmental conditions of the measurement: (temperature and humidity with limits of variation.
Temperature: (23 ±1) ° C
Relative Humidity: (40 ± 10) %

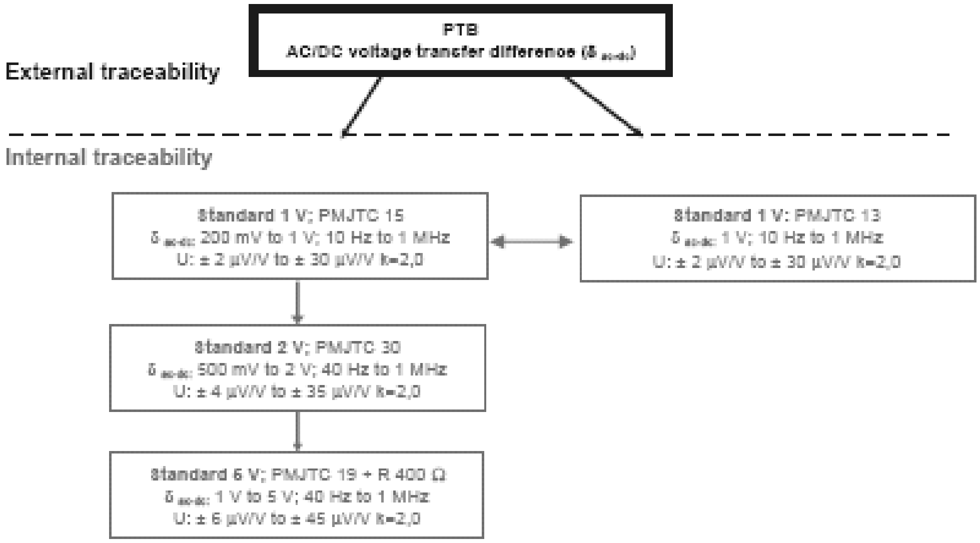
Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V			Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
3 V / 1 kHz	1,1	0,9	1,7	± 6	2,0
3 V / 20 kHz	2,7	2,5	2,9	± 6	2,0
3 V / 100 kHz	14,8	16,3	13,5	± 8	2,0
3 V / 1 MHz	0,0	4,4	6,2	± 38	2,0

The reference standard, and its traceability to de SI

At 3 V the traveling standard was calibrated against the 5 V CENAM standard, a 90 Ω planar multijunction thermal converter (PMJTC) in series with a 400 Ω coaxial resistor.

The δ values of the 5 V standard are the result of a step up in voltage performed at CENAM, calibrating it against the 2 V CENAM standard (400 Ω PMJTC) whose δ values were calibrated against the1 V CENAM standard (90 Ω PMJTC), whose values are traceable to the δ values of the PTB standards.



Uncertainty Budget

SIM.EM-K6a (3 V)																							
Uncertainty component	Estimate x_i				Relative standard uncertainty $u(x_i)$				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i			uncertainty contribution $u_i(\delta)$				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																							
• Reference Standard calibration	0,3	2,0	8,7	117,4	2	2	3	17	Normal B	Normal B	Normal B	Normal B	1	1	1	2	2	3	17	60	60	60	60
• Reference standard stability					1	1	2	7	Normal B	Normal B	Normal B	Normal B	1	1	1	1	1	2	7	9	9	9	9
Difference measurement:	0,8 0,6 1,4	0,7 0,5 0,9	6,1 7,6 4,8	-117,4 -113,0 -111,2																			
• Standard deviation of measurements					0,1 0,4 0,1	0,1 0,1 0,1	0,1 0,4 0,1	0,1 2,0 0,1	Normal A	Normal A	Normal A	Normal A	1	1	1	0,1 0,4 0,1	0,1 0,1 0,1	0,1 0,4 0,1	0,1 2,0 0,1	20	20	20	20
• Nanovoltmeters short time stability and measurement set up					1,7	1,7	1,7	1,7	Rectangular B	Rectangular B	Rectangular B	Rectangular B	1	1	1	1,7	1,7	1,7	1,7	60	60	60	60
δ	**1,1** **0,9** **1,7**	**2,7** **2,5** **2,9**	**14,8** **16,3** **13,5**	**0,0** **4,4** **6,2**															ν_{eff}	113 130 113	113 113 113	73 73 73	69 71 69

REPORT OF RESULTS
SIM.EM-K9

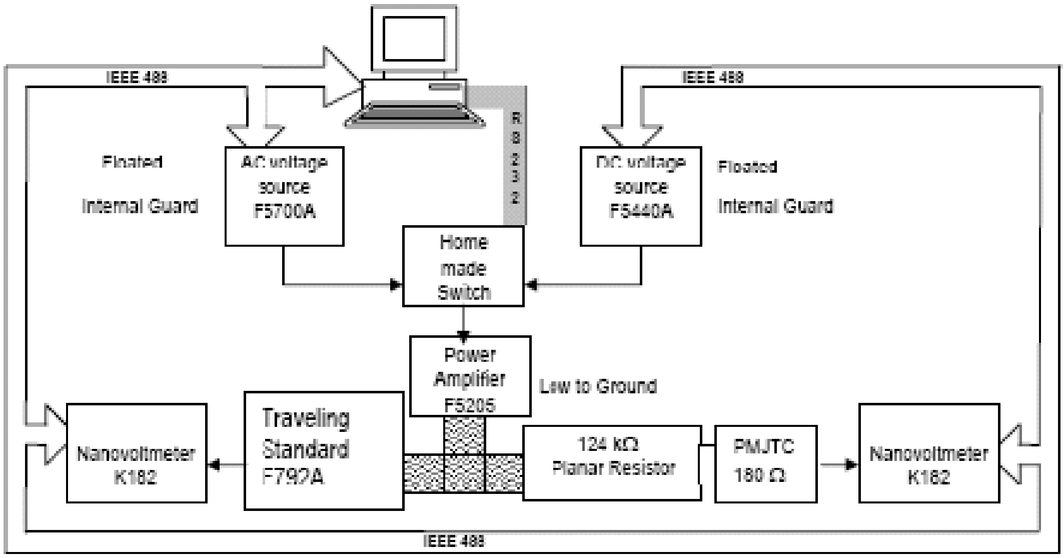
Participating laboratory: Centro Nacional de Metrología, México
Date of measurements: 2nd to 4th December 2003
7th to 24th August 2004
10th and 11th November 2004

Description of the measuring method:

The two channel method was used to calibrate the traveling standard against a reference thermal voltage converter, using nanovoltmeters to measure the thermal converters output. The plan of reference was the center of a type N tee connector. Two voltage sources and one power amplifier were used to apply the AC and the DC voltage to the thermal converters using an external fast response switch. The AC and the DC voltage sources were connected to the input of the external switch and the output of this one was connected to the input of the power amplifier (1:100) whose output was connected to the input of the thermal converters. To minimize the thermal drift the sequence AC, DC+, AC, DC- AC was executed allowing AC-DC stabilization time of 90 seconds. The measurement system ran automatically.

During the measurements the DC and the AC voltage sources were floated and configured with internal guard. At the power amplifier the low terminal and ground were connected together.

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (23±1) ° C

Relative Humidity: (40± 10) %

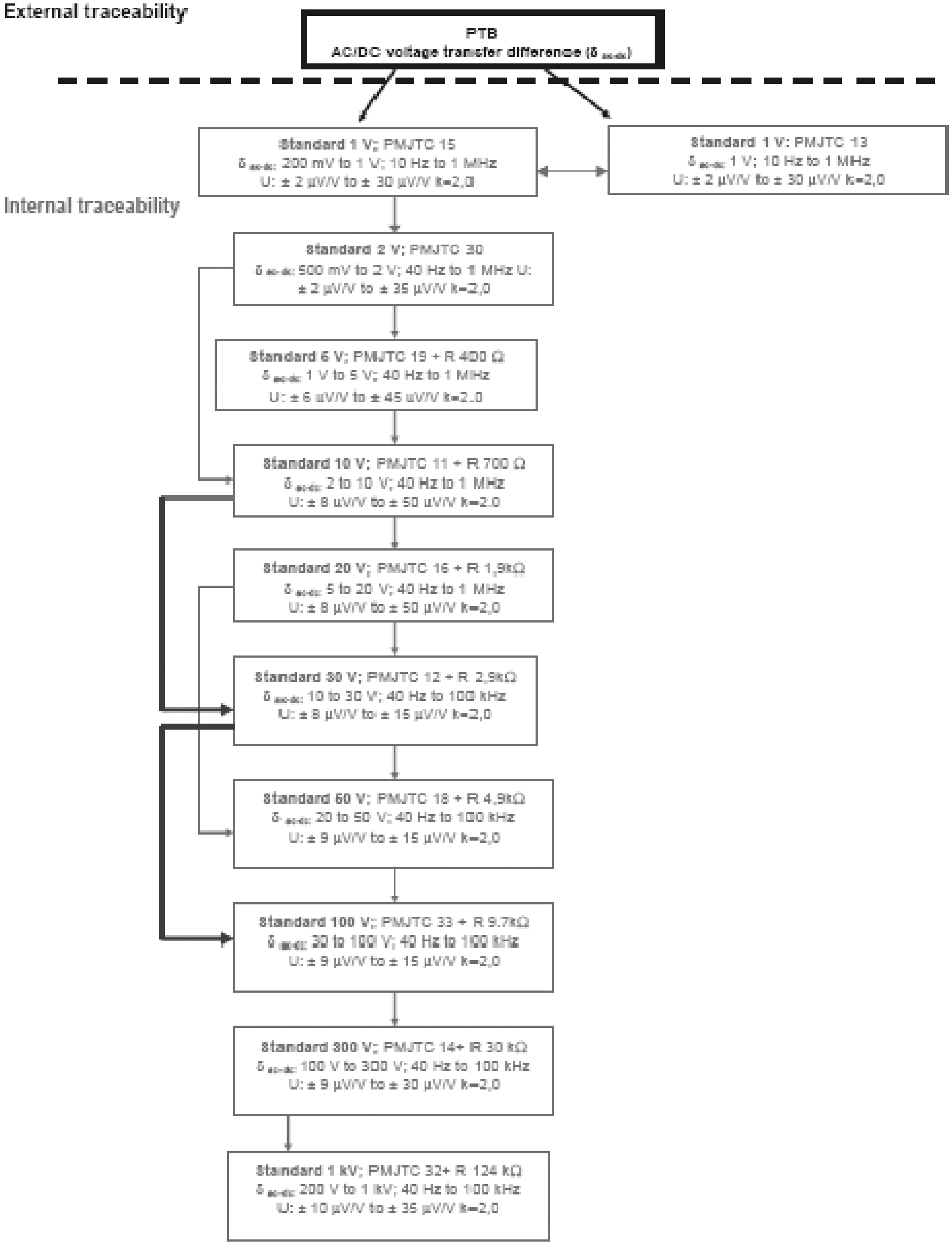
Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) μV/V			Uncertainty of the AC-DC voltage transfer difference (U_δ) μV/V	Coverage factor
1000 V / 1 kHz	4,3	5,7	4,0	15	2,1
1000 V / 10 kHz	1,4	4,2	3,8	15	2,1
1000 V / 20 kHz	-0,3	3,9	2,5	17	2,1
1000 V / 50 kHz	-4,1	3,3	1,1	27	2,3
1000 V / 100 kHz	-7,1	3,9	-2,0	27	2,3

The reference standard, and its traceability to de SI

At 1 kV the traveling standard was calibrated against the 1 kV CENAM standard a 180 Ω planar multijunction thermal converter (PMJTC), in series with a 124 kΩ planar resistor,

The δ values of the 1 kV CENAM standard are the result of a step up in voltage, performed at CENAM, following the procedure described in the next diagram. Theδ values of the PMJTC in the first step are traceable to the values of the PTB standards.


External traceability
PTB
AC/DC voltage transfer difference (δ ac-dc)
Standard 1 V; PMJTC 15
δ ac-dc: 200 mV to 1 V; 10 Hz to 1 MHz
U: ± 2 µV/V to ± 30 µV/V k=2,0
Standard 1 V: PMJTC 13
δ ac-dc: 1 V; 10 Hz to 1 MHz
U: ± 2 µV/V to ± 30 µV/V k=2,0
Internal traceability
Standard 2 V; PMJTC 30
δ ac-dc: 500 mV to 2 V; 40 Hz to 1 MHz U:
± 2 µV/V to ± 35 µV/V k=2,0
Standard 6 V; PMJTC 19 + R 400 Ω
δ ac-dc: 1 V to 5 V; 40 Hz to 1 MHz
U: ± 6 µV/V to ± 45 µV/V k=2,0
Standard 10 V; PMJTC 11 + R 700 Ω
δ ac-dc: 2 to 10 V; 40 Hz to 1 MHz
U: ± 8 µV/V to ± 50 µV/V k=2,0
Standard 20 V; PMJTC 16 + R 1,9kΩ
δ ac-dc: 5 to 20 V; 40 Hz to 1 MHz
U: ± 8 µV/V to ± 50 µV/V k=2,0
Standard 30 V; PMJTC 12 + R 2,9kΩ
δ ac-dc: 10 to 30 V; 40 Hz to 100 kHz
U: ± 8 µV/V to ± 15 µV/V k=2,0
Standard 60 V; PMJTC 18 + R 4,9kΩ
δ ac-dc: 20 to 50 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 15 µV/V k=2,0
Standard 100 V; PMJTC 33 + R 9.7kΩ
δ ac-dc: 30 to 100 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 15 µV/V k=2,0
Standard 300 V; PMJTC 14+ R 30 kΩ
δ ac-dc: 100 V to 300 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 30 µV/V k=2,0
Standard 1 kV; PMJTC 32+ R 124 kΩ
δ ac-dc: 200 V to 1 kV; 40 Hz to 100 kHz
U: ± 10 µV/V to ± 35 µV/V k=2,0

Uncertainty budget

SIM.EM-K9 (1000 V)																																			
Uncertainty component	Estimate x_i					Relative standard uncertainty $u(x_i)$					Probability Distribution / Method of evaluation (A, B)					Sensitivity coefficient c_i					uncertainty contribution $u_i(\delta)$					Degree of freedom ν_i				
Frequencies (kHz)	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100	1	10	20	50	100
Reference Standard:																														
• Reference Standard calibration	-1,3	-3,3	-3,8	-5.9	-8,9	6	6	6	6	6	Normal B	Normal B	Normal B	Normal B	Normal B	1	1	1	1	1	6	6	6	6	6	60	60	60	60	60
• Reference standard stability						4	4	5	10	10	Normal B	Normal B	Normal B	Normal B	Normal B	1	1	1	1	1	4	4	5	10	10	6	6	6	6	6
Difference measurement:	5,6 7,0 5,3	4,7 7,5 7,1	3,5 7,7 6,3	1,8 9,2 6,7	1,8 12,8 6,9																									
• Standard deviation of measurements						0,2 0,2 0,1	0,1 0,2 0,1	0,3 0,2 0,2	0,3 0,3 0,1	0,3 0,4 0,2	Normal A	Normal A	Normal A	Normal A	Normal A	1	1	1	1	1	0,2 0,2 0,1	0,1 0,2 0,1	0,3 0,2 0,2	0,3 0,3 0,1	0,3 0,4 0,2	20	20	20	20	20
• Nanovoltmeters short time stability						1,7	1,7	1,7	1,7	1,7	Rectangular B	Rectangular B	Rectangular B	Rectangular B	Rectangular B	1	1	1	1	1	1.7	1.7	1.7	1.7	1.7	60	60	60	60	60
δ	4,3 5,7 4,0	1,4 4,2 3,8	-0,3 3,9 2,5	-4,1 3,3 1,1	-7,1 3,9 -2,0																ν_{eff}					41	41	28	10	10

REPORT OF RESULTS
SIM.EM-K11

Participating laboratory: Centro Nacional de Metrología, México

Date of measurements:
10th to 16th December
26th to 30th August 2004
24th November to 1st December 2004

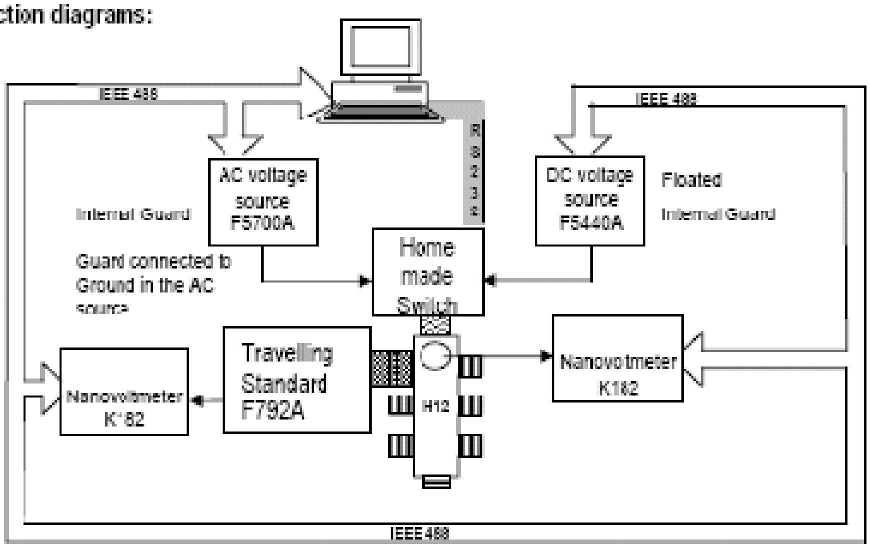
Description of the measuring method:

The travelling standard was calibrated at 200 mV against a 90 Ω planar multijunction thermal converter (PMJTC) later a micropotentiometer was used to step down up to 100 mV. Using the two channel method, two nanovoltmeters were used to measure the thermal converters output. Two voltage sources were used to apply the AC and the DC voltage to the thermal converters using an external fast response switch. To minimize the thermal drift the sequence AC, DC+, AC, DC- AC was executed allowing AC-DC stabilization time of 90 seconds during the calibration against the PMJTC and 60 seconds during the calibration against the micropotentiometer. The measurement system ran automatically.

At the millvolt level, when operated at frequencies higher than 100 kHz, the input impedance of the travelling standard decrease considerably. This decrease cause changes in the ac voltage delivered by the source, the δ must be corrected because of the loading effect. However during the step down procedure the loading effects were canceled.

During the measurements the DC and the AC voltage sources were configured with internal guard, the DC voltage source was floated and in the AC source guard and ground terminals were connected together.

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation

Temperature: (23±1) ° C

Relative Humidity: (40± 10) %

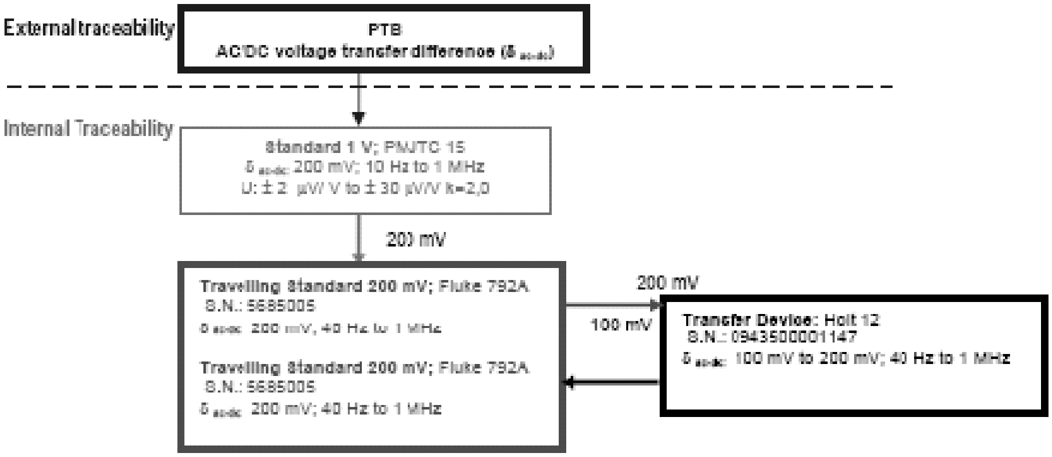
Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V			Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
100 mV / 1 kHz	4,2	7,5	2,2	± 23	2,0
100 mV / 20 k Hz	-2,9	-6,0	-4,4	± 23	2,0
100 mV / 100 kHz	20,0	21,6	20,3	± 23	2,0
100 mV / 1 MHz	55,2	59,9	61,1	± 42	2,0

The reference standard, and its traceability to de SI

At 100 mV the traveling standard was calibrated against a micropotentiometer assuming it is level independent. During the stay of the travelling standard, the micropotentiometer was calibrated at 200 mV against the traveling standard, this one previously calibrated against a 90 Ω planar multijunction thermal converter, that is the CENAM 1 V standard.

The δ values of the 1 V CENAM standard are traceable to the δ values of the PTB standards.



Uncertainty budget

SIM.EM-K11 (100 mV)

Uncertainty component	Estimate x_i				Relative standard uncertainty $u(x_i)$				Probability Distribution / Method of evaluation (A, B)				Sensitivity coefficient c_i				uncertainty contribution $u_i(\delta)$				Degree of freedom ν_i			
Frequencies (kHz)	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000	1	20	100	1000
Reference Standard:																								
• Reference Standard calibration	-9,1 -5,3 -9,1	-11,9 -13,3 -11,9	-3,2 0,2 -3,2	-123,8 -114,4 -123,8	4,4	4,4	5,1	18	Normal B	Normal B	Normal B	Normal B	1	1	1	1	4,4	4,4	5,1	18	60	60	60	60
• Reference standard level dependence					10	10	10	10	Normal B	Normal B	Normal B	Normal B	1	1	1	1	10	10	10	10	60	60	60	60
Difference measurement:	13,3 12,8 11,3	9,0 7,3 7,5	23,2 21,4 23,5	179,0 174,3 184,9																				
• Standard deviation of measurements					0,0 0,1 0,5	0,2 0,2 0,4	0,1 0,2 0,5	0,1 0,1 0,3	Normal A	Normal A	Normal A	Normal A	1	1	1	1	0,0 0,1 0,5	0,2 0,2 0,4	0,1 0,2 0,5	0,1 0,1 0,3	20	20	20	20
• Nanovoltmeters short time stability					1,7	1,7	1,7	1,7	Rectagular B	Rectagular B	Rectagular B	Rectagular B	1	1	1	1	1,7	1,7	1,7	1,7	60	60	60	60
δ	**4,2 7,5 2,2**	**-2,9 -6,0 -4,4**	**20,0 21,6 20,3**	**55,2 59,9 61,1**																ν_{eff}	86 88 88	86 86 89	93 93 93	96 96 96

REPORT OF RESULTS
120 V

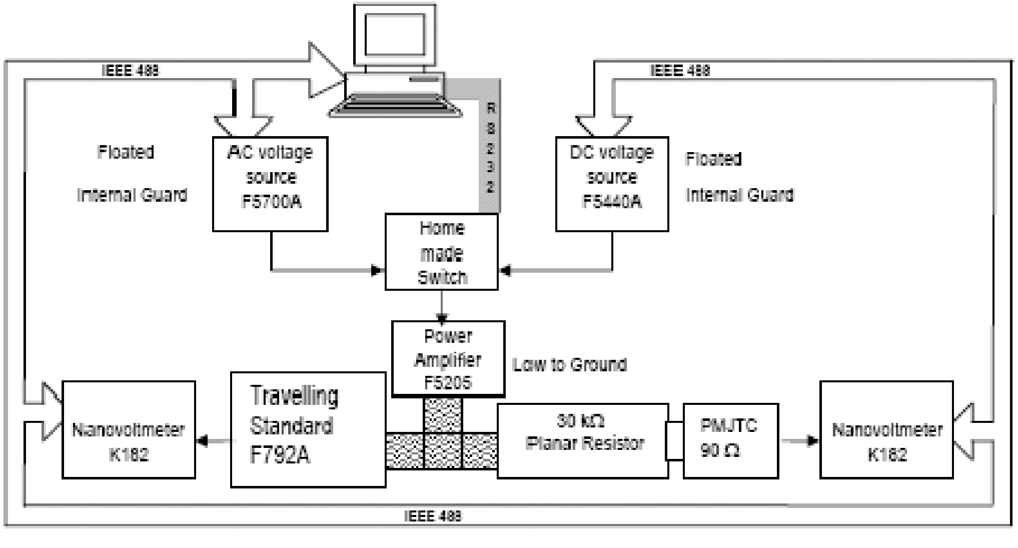
Participating laboratory: Centro Nacional de Metrología, México
Date of measurements: 2nd to 4th December 2003
7th to 24th August 2004
10th and 11th Nowember 2004

Description of the measuring method:

The two channel method was used to calibrate the travelling standard against a reference thermal voltage converter, using nanovoltmeters to measure the thermal converters output. The plan of reference was the center of a type N tee connector. Two voltage sources and one power amplifier were used to apply the AC and the DC voltage to the thermal converters using an external fast response switch. The AC and the DC voltage sources were connected to the input of the external switch and the output of this one was connected to the input of the power amplifier (1:100) whose output was connected to the input of the thermal converters. To minimize the thermal drift the sequence AC, DC+, AC, DC- AC was executed allowing AC-DC stabilization time of 90 seconds. The measurement system ran automatically.

During the measurements the DC and the AC voltage sources were floated and configured with internal guard. At the power amplifier the low terminal and ground were connected together.

Connection diagrams:



Environmental conditions of the measurement: (temperature and humidity with limits of variation
Temperature: (23±1) ° C
Relative Humidity: (40± 10) %

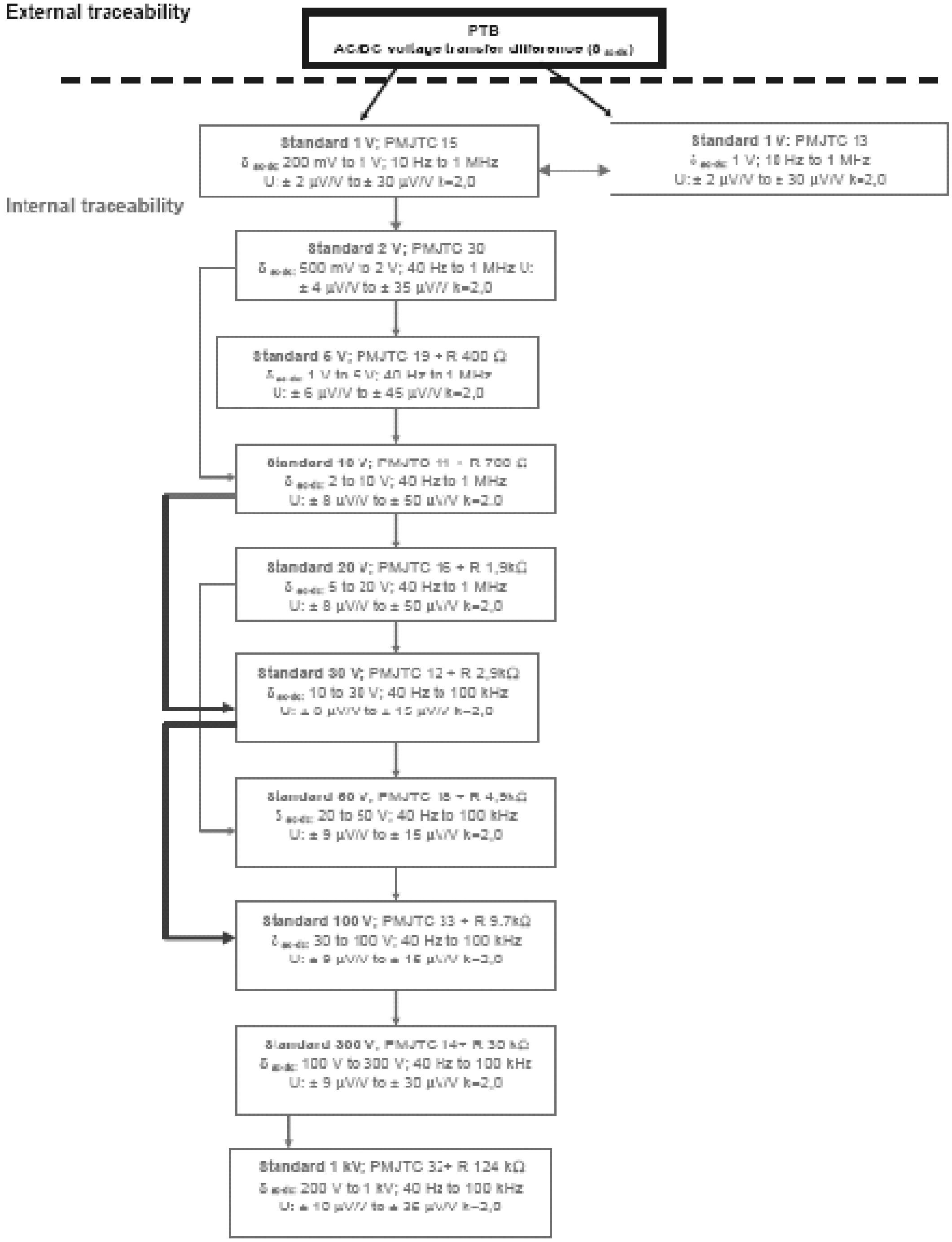
Results of measurements:

Measurement point	AC-DC voltage transfer difference (δ) µV/V			Uncertainty of the AC-DC voltage transfer difference (U_δ) µV/V	Coverage factor
120 V / 53 Hz	3,8	2,3	2,4	11	2,0

The reference standard, and its traceability to de SI

At 120 V the traveling standard was calibrated against the 300 V CENAM standard a 90 Ω planar multijunction thermal converter (PMJTC), in series with a 30 kΩ planar resistor,

The δ values of the 300 V CENAM standard are the result of a step up in voltage, performed at CENAM, following the procedure described in the next diagram. The δ values of the PMJTC in the first step are traceable to the values of the PTB standards.


External traceability
PTB
AC/DC voltage transfer difference (δ_{ac-dc})
Internal traceability
Standard 1 V; PMJTC 15
δ_{ac-dc}: 200 mV to 1 V; 10 Hz to 1 MHz
U: ± 2 µV/V to ± 30 µV/V k=2,0
Standard 1 V: PMJTC 13
δ_{ac-dc}: 1 V; 10 Hz to 1 MHz
U: ± 2 µV/V to ± 30 µV/V k=2,0
Standard 2 V; PMJTC 30
δ_{ac-dc}: 500 mV to 2 V; 40 Hz to 1 MHz U: ± 4 µV/V to ± 35 µV/V k=2,0
Standard 6 V; PMJTC 19 + R 400 Ω
δ_{ac-dc}: 1 V to 6 V; 40 Hz to 1 MHz
U: ± 6 µV/V to ± 45 µV/V k=2,0
Standard 10 V; PMJTC 11 + R 700 Ω
δ_{ac-dc}: 2 to 10 V; 40 Hz to 1 MHz
U: ± 8 µV/V to ± 50 µV/V k=2.0
Standard 20 V; PMJTC 16 + R 1,9kΩ
δ_{ac-dc}: 5 to 20 V; 40 Hz to 1 MHz
U: ± 8 µV/V to ± 50 µV/V k=2,0
Standard 30 V; PMJTC 12 + R 2,9kΩ
δ_{ac-dc}: 10 to 30 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 15 µV/V k=2,0
Standard 60 V; PMJTC 18 + R 4,9kΩ
δ_{ac-dc}: 20 to 60 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 15 µV/V k=2,0
Standard 100 V; PMJTC 33 + R 9.7kΩ
δ_{ac-dc}: 30 to 100 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 16 µV/V k=2,0
Standard 300 V; PMJTC 14+ R 30 kΩ
δ_{ac-dc}: 100 V to 300 V; 40 Hz to 100 kHz
U: ± 9 µV/V to ± 30 µV/V k=2,0
Standard 1 kV; PMJTC 32+ R 124 kΩ
δ_{ac-dc}: 200 V to 1 kV; 40 Hz to 100 kHz
U: ± 10 µV/V to ± 26 µV/V k=2,0

Uncertainty budget

120 V / 53 Hz

Uncertainty component	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability Distribution / Method of evaluation (A, B)	Sensitivity coefficient c_i	uncertainty contribution $u_i(\delta)$	Degree of freedom ν_i
Reference Standard:	-1,1					
• Reference Standard calibration		5,0	Normal / B	1	5,0	80
• Reference standard stability		1,0	Normal / B	1	1,0	5
Difference measurement:	4,9 3,4 3,5					
• Standard deviation of measurements		0,5 0,5 0,5	Normal / A	1	0,5 0,5 0,5	10
• Nanovoltmeters short time stability		1,7 1,7 1,7	Rectangular / B	1	1,7 1,7 1,7	60
δ	3,8 2,3 2,4				ν_{eff}	79

END OF THE REPORT