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Bilateral comparison between EIM and IMBiH in DC Voltage
Calibration of a Zener DC voltage standard of 10 V

Myrto Holiastou
Head of Low Frequency Laboratory
HELLENIC INSTITUTE OF METROLOGY (EIM)
Industrial Area of Thessaloniki
Block 45, Sindos, GR 57022
Thessaloniki ,Greece
Web: www.eim.gr
E-mail: holiastou@eim.gr

CONTENTS

1. INTRODUCTION

The present intercomparison was proposed by the Institute of Metrology of Bosnia and Herzegovina (IMBiH), with the motive of supporting its CMCs in the quantity of Voltage. The Hellenic Institute of Metrology (EIM) and the laboratory of Low Frequency of the Electrical Measurements Department was the pilot of the intercomparison and the travelling standard was provided by IMBiH.

The steps for the transport of the standard, the timetable of measurements and the reporting formulations were described in the protocol of the intercomparison, which was prepared following the CCEM guidelines.

2. DETAILS

2.1 Participants

The Pilot laboratory was the Low Frequency laboratory of the Hellenic Institute of Metrology:

HELLENIC INSTITUTE OF METROLOGY (EIM)
Industrial Area of Thessaloniki
Block 45, Sindos, GR 57022
Thessaloniki ,Greece
Web: www.eim.gr

EIM Contact person:
Myrto Holiastou
Tel.: 2310 569 971, 2310-569999
Fax: 2310 569 996
e-mail: holiastou@eim.gr

The participating laboratory was IMBiH:

Institute of Metrology of Bosnia and Herzegovina (IMBiH)
Laboratory for electrical quantities and T&F
Augusta Brauna 2
71000, Sarajevo
Bosnia and Herzegovina
web: www.met.gov.ba

IMBiH Contact person:
Vladimir Milojević
Tel: ++387 33 568 924
Fax: ++387 33 568 909
e-mail: vladimir.milojevic@met.gov.ba

2.2 Timetable

The measurements were performed according to the following timetable:

Time table of the Measurments

Institute	Action	Time period
IMBiH	Perform IMBiH measurements	1-10 July 2015
EIM	Perform EIM measurements	27-31 July 2015
IMBiH	Perform IMBiH measurements	12-21 August 2015

2.3 Travelling standard

The travelling standard was a voltage standard of the Zener type provided by IMBiH. The measured voltage was the 10 V output of the Zener and the measurements were performed by the two institutes, EIM and IMBiH minimizing the time interval between them. Its transport was done with the external battery of the Zener connected to it. The "INCAL" led of the Zener was always ON throughout the intercomparison.

The travelling standard had the following characteristics:

DC Reference standard

Device: Zener
Nominal value: 10 Volt
Manufacturer: Fluke
Type: 732B
Serial Number: 2231035

External battery: Fluke 732B-7001
Serial number: 221002

3. MEASUREMENTS

3.1 Methods of measurement

The participating laboratory described the method of measurement and the environmental conditions within its report, as it was requested in the protocol of the comparison. The calibration was performed as follows:

The measurements were made using a System for calibration DC voltage Reference Standards.
The system for calibration DC voltage Reference Standard consist: 4 zener cells, Low Thermal Scanner (32 channels), nanovoltmeter Keithly 2182A and PC with program VoltRef.

The unknown DC voltage Reference Standard placed in system for calibration DC voltage with three known DC Reference Standards. All DC voltage Reference Standard must be disconnect from power during calibration. For three known DC Reference Standards indication light "INCAL" must be ON. For the estimation of the reproducibility, the measurement must be repeated at least five different days. Value of unknown DC voltage Reference Standard is defined as mean value of values determined by comparison with three known DC Reference Standards

The pilot laboratory used the method of comparing the travelling standard with the primary Josephson voltage standard of EIM. The measurement system was manufactured by Hypres Inc. (USA) and comprised of:

- Josephson array of SIS type
- Helium dewar 120 lit
- Microwave gun system 74-76 GHz
- Counter EIP 578B
- Nanovoltmeter of type HP34420A

For the automation of the measurements the NISTVOLT software for windows prepared by NIST was used.

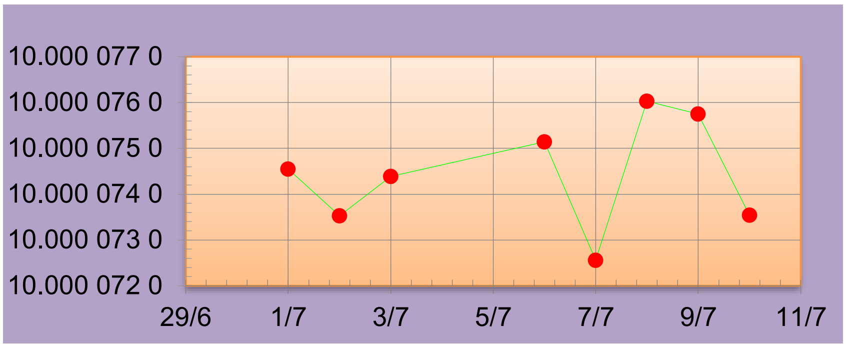
3.2 IMBiH Results

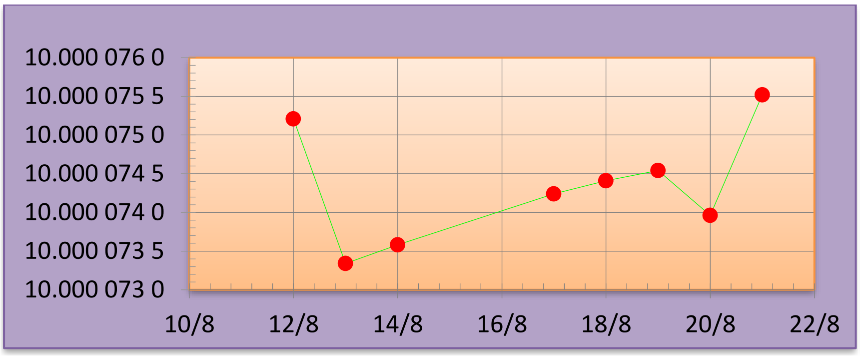
IMBiH performed the measurements at two times, one before and one after the measurements of the pilot lab. Its results were the following:

IMBiH Results 10 V

Date of measurement	Temperature	Humidity	Measurement result	Stdev
01.07.2015	23.34	48.94	10.000 074 55	5.18E-09
02.07.2015	23.12	49.32	10.000 073 53	4.03E-09
03.07.2015	22.74	50.67	10.000 074 39	5.03E-09
06.07.2015	22.76	50.89	10.000 075 14	5.01E-09
07.07.2015	22.75	51.38	10.000 072 56	3.82E-09
08.07.2015	22.83	49.73	10.000 076 03	5.02E-09
09.07.2015	22.89	50.20	10.000 075 75	4.88E-09
10.07.2015	22.82	46.50	10.000 073 54	4.40E-09
(EIM Measurements)				
12.08.2015	23.04	45.08	10.000 075 21	5.95E-09
13.08.2015	22.91	44.24	10.000 073 34	4.17E-09
14.08.2015	22.90	44.90	10.000 073 58	8.25E-09
17.08.2015	22.69	51.00	10.000 074 24	3.49E-09
18.08.2015	22.68	50.01	10.000 074 41	4.22E-09
19.08.2015	22.78	47.01	10.000 074 54	4.10E-09
20.08.2015	22.84	48.92	10.000 073 96	4.42E-09
21.08.2015	22.74	48.35	10.000 075 52	5.61E-09

In the following graphs the results of MBiH are presented as a function of the date.





The reported result of IMBiH is the following:

Reported by IMBiH			
Date	Voltage (V)	uc (V)	*U* (*k*=2) (V)
7/7/2015	10. 000 074 436	0.000 018	0.000 035
15/8/2015	10. 000 074 350	0.000 018	0.000 035

3.3 EIM Reference value

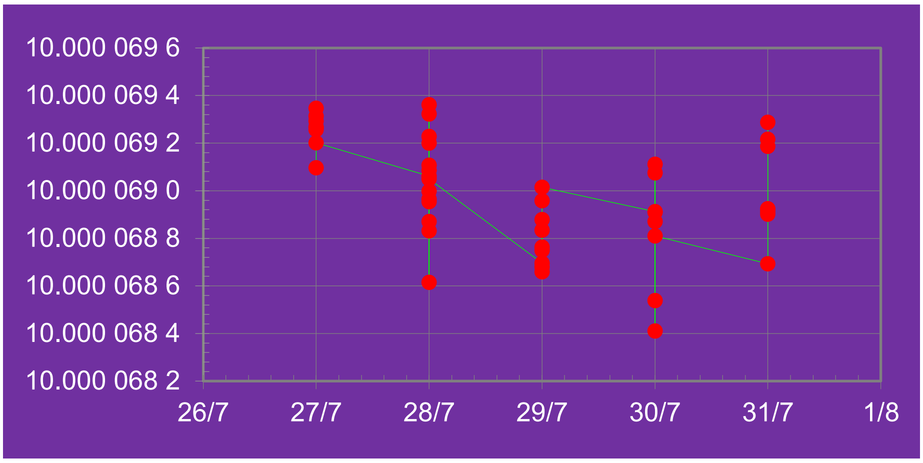
EIM performed measurements of the Zener once, between the two measurements of IMBiH. In total 50 measurements of the Zener standard compared to the Josephson standard were taken.

EIM MEASUREMENTS

Date	Time	Meas. Voltage (V)	u_c (nV)
27 July 2015	10:30	10.0000691	45
27 July 2015	10:37	10.00006931	37
27 July 2015	10:44	10.00006935	27
27 July 2015	10:52	10.00006926	28
27 July 2015	14:46	10.00006929	43
27 July 2015	14:54	10.00006927	29
27 July 2015	15:02	10.00006927	27
27 July 2015	15:11	10.0000692	30
28 July 2015	10:53	10.00006906	32
28 July 2015	11:00	10.00006911	27
28 July 2015	11:07	10.00006897	30
28 July 2015	11:15	10.00006862	33

28 July 2015	11:25	10.0000692	28
28 July 2015	11:37	10.00006923	29
28 July 2015	11:44	10.00006936	27
28 July 2015	11:52	10.00006932	28
28 July 2015	14:53	10.00006883	28
28 July 2015	15:00	10.00006895	30
28 July 2015	15:08	10.000069	26
28 July 2015	15:18	10.00006887	32
28 July 2015	15:25	10.00006909	28
28 July 2015	15:34	10.00006905	30
29 July 2015	09:50	10.0000687	34
29 July 2015	09:57	10.00006875	29
29 July 2015	10:04	10.00006866	38
29 July 2015	12:50	10.00006883	29
29 July 2015	12:57	10.00006888	28
29 July 2015	13:04	10.00006868	55
29 July 2015	14:32	10.00006876	29
29 July 2015	14:39	10.00006896	28
29 July 2015	14:46	10.00006902	33
30 July 2015	10:43	10.00006891	29
30 July 2015	10:51	10.00006891	28
30 July 2015	10:58	10.00006908	31
30 July 2015	11:05	10.00006911	33
30 July 2015	14:12	10.00006887	33
30 July 2015	14:19	10.00006854	35
30 July 2015	14:27	10.00006841	38
30 July 2015	14:34	10.00006881	59
31 July 2015	10:09	10.00006869	27
31 July 2015	10:17	10.00006892	34
31 July 2015	10:24	10.00006893	31
31 July 2015	10:31	10.0000689	30
31 July 2015	12:47	10.00006891	29
31 July 2015	12:54	10.00006922	31
31 July 2015	13:00	10.00006919	32
31 July 2015	13:08	10.00006929	33
31 July 2015	14:02	10.00006905	27
31 July 2015	14:09	10.00006908	28
31 July 2015	14:16	10.0000689	43
31 July 2015	14:23	10.00006901	32

A graph of EIM's measurements is presented below. The reference value of the intercomparison is calculated as the average of the above values and the reference date is considered as the mean date of the measurements.



EIM 10 V Reference value

Date	Zener Voltage (V)	uc (V)	*U* (*k*=2) (V)
29 July 2015	10.000 068 993	0.000 000 47	0.000 000 93

4. UNCERTAINTY

The uncertainty of the measurements was calculated by both laboratories according to the international standards ISO "Guide to the Expression of Uncertainty in Measurement", 1995 and the standard EA-4/02. The uncertainty budget of IMBiH is presented in the Appendix.

4.1 Expanded Uncertainty

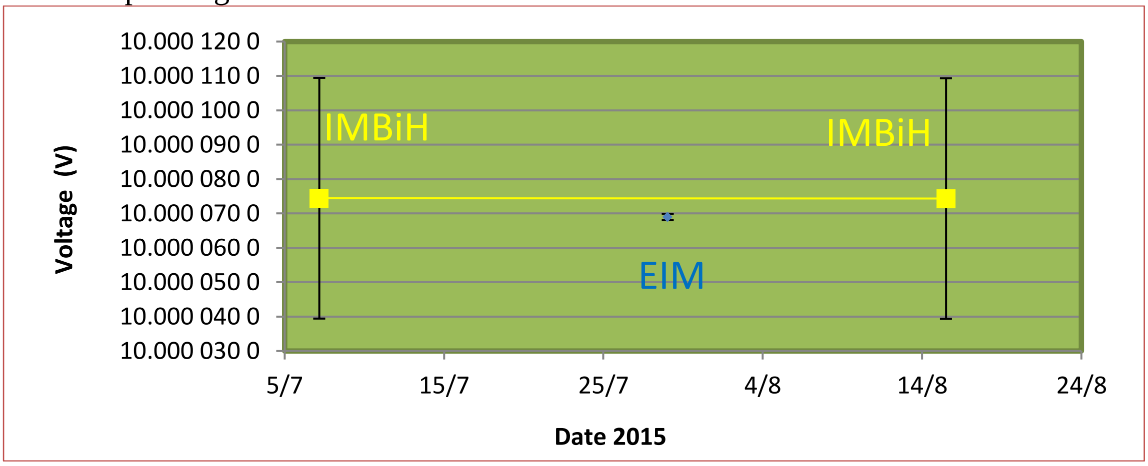
The expanded uncertainty for a level of confidence of 95% is given by the relation:

$U = 1{,}96\, u$

Where u is the combined standard uncertainty.

5. EVALUATION OF THE RESULTS

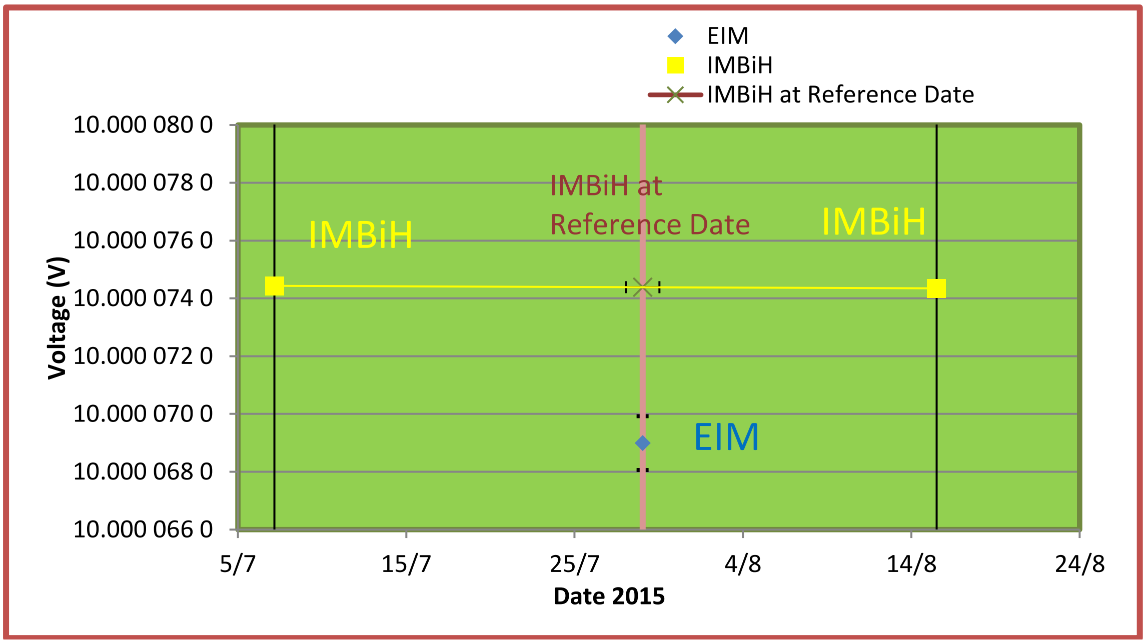
In the next graph the results of the participating laboratory and the pilot laboratory are presented with the corresponding uncertainties as error bars.



5.1 IMBiH at the Reference Date

A linear regression between the two IMBiH measurements gives the a, b constants of the line connecting the two measurements, i.e. intersection and slope. Using the constants a and b the value of the zener voltage at the chronological point of the EIM measurements can be computed. This will be compared directly with the reference value of EIM calculated before. The results of the calculation are presented below:

IMBiH value at the Reference Date				
Reference Date	**Resistance (Ω)**	***U* (*k*=2) (V)**	a=	-2.193E-09 V/day
29 July 2015	10.000 074 388	0.000 035	b=	10.000 074 44 V



5.2 Comparison IMBiH-EIM

Having computed the value of IMBiH corresponding to the reference date, the difference with the pilot lab result can be computed directly.

Comparison EIM-IMBiH

Nominal Voltage	IMBiH-EIM Difference (μV)	IMBiH-EIM Difference (ppm)	Expanded Uncertainty *U* (*k*=2) (μV)
10 V	5.4	0.54	89.1

5.3 Index E_n

According to the directive EA-2/03 “Interlaboratry Comparisons”, the evaluation of the measurement results is performed with the estimation of the parameter E_n, which is defined as:

$$E_n = \frac{V_{LAB} - V_{EIM}}{\sqrt{U^2(V_{LAB}) + U^2(V_{EIM})}}$$ where,

V_{LAB} is the error measured by the participating lab

V_{EIM} is the error measured by the pilot lab

$U(V_{LAB})$ is the expanded uncertainty of the participating lab and

$U(V_{EIM})$ is the expanded uncertainty of the pilot lab.

All the values of En are expected to be less than unity: $|E_n| < 1$.

In the next table all the values of En are presented for the participating laboratory.

***En* values of the intercomparison**

Nominal value	*En*
10 V	-0.14

5.4 Conclusion

The value of the index En is less than unity in absolute value $|En| < 1$ as it is expected.

APPENDIX

IMBiH Uncertainty Budget

10 V Uncertainty Budget IMBiH

Quantity X_i	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability distribution / method of evaluation (A, B)	Sensitivity coefficient c_i	Relative uncertainty contribution $u(R_i)$	Degree of freedomn ν_i
UUT value of zener V_x	10.000 074	0.002	Normal	1	1.62E-09	383
Calibration V_s (Certificate) V_{cert}	0	0.25	Normal	1	2.50E-06	∞
Drift V_s, 3 year V_{drift}	0	1.73	Rectangular	1	1.73E-05	∞
Temp. Coeff. Vtemp	0	0.023	Rectangular	1	2.31E-07	∞
Nanovoltmeter resolution V_{res}	0	0.03	Rectangular	1	2.89E-07	∞
Nanovoltmeter specification V_{spec}	0	0.026	Rectangular	1	2.60E-08	∞
R_x	10.000 074					
		Combined standard uncertainty:				*0.000018*
		Degrees of freedom:				*5.19E+18*
		Expanded uncertainty (coverage factor 95%):				*0.000035*