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Inter-laboratory comparison of calibration results for frequency counter between INM MD and UzNIM

Vohobjon Nishonov [(1)], Andrei Gherlih [(2)], and Sheroz Ismatullayev [(1)]
(1) Uzbek National Institute of Metrology, Republic of Uzbekistan
(2) National Institute of Metrology, Republic of Moldova

Abstract

Results of inter-laboratory comparison show competency of calibration laboratories and assure quality of measurements and calibration performed by laboratories. Besides if laboratories want to demonstrate that they operate management system based on ISO/IEC 17025 [2] requirements [1]. This research work also aimed to ensure validity of results in the field of calibration of frequency counter between National Institute of Metrology, Republic of Moldova (INM MD) and Uzbek National Institute of Metrology, Republic of Uzbekistan (UzNIM). Inter-laboratory comparison was carried out during 2022 and 2023 years according to the ISO/IEC 17043 [3] and reached positive results.

1. Introduction

In the era of technology and engineering it is the most important to provide single measurement unit among the countries and metrological traceability of each measurement units to the SI units. In order to achieve every country has its own measurement infrastructure which involves a National Metrology Institute (NMI) a network of calibration laboratories and a larger number of organizations for which the traceability of the measuring devices to national measurement standards has to be assured [4].

Participants of inter-laboratory comparison, In the Republic of Moldova National Institute of Metrology (INM MD) [5] and in the Republic of Uzbekistan Uzbek National Institute of Metrology (UzNIM) [6] generally deals with following activities:
- Implementation of the policy in metrology at the national level;
- Creation, development and maintenance of national measurement standards, keeping and transfer of legal units of measurement;
- Provision of traceability of measurements results by carrying out comparisons of national measurement standards at the regional and international level, calibration of national measurement standards;
- Training and upgrading of skills of specialists, performing works in the field of metrology;
- Preparation and expertise of draft normative and technical documents on ensuring the uniformity of measurements, harmonized with international and national documents of other countries in terms of metrological requirements.

It was agreed that INM MD would be the pilot laboratory for this comparison. The role of the pilot calibration laboratory is to accompany the process and to evaluate the measurement results. The methodical approach is according to ISO/IEC 17043:2010 "Conformity assessment - General requirements for proficiency testing".
The tasks of the pilot laboratory:
- Prepare the comparison protocol;
- Characterize and calibrate of stopwatch;
- Perform the analysis of the comparison data and elaborate the final report.
The tasks of participant laboratory UzNIM:
- Perform the measurements according to the rules of this protocol;
- Send to the coordinator comparison results in 15 days after finishing the measurements.

2. Methods and Materials

Comparison schedule

The scheme of the bilateral comparison is presented in figure 1. Based on scheme measurements were firstly performed in the INM MD laboratory and secondly in the UzNIM laboratory.

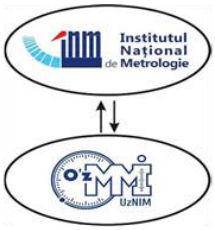

Figure 1. Bilateral comparison scheme

The comparison measurement was executed as a bilateral comparison measurement. All information in connection with this comparison were officially published in CTS (Scientific Technical Council of INM MD) as an "Final Report of bilateral inter-laboratory comparison Comparison of calibration results for frequency counter MD/096/23" [7].

Description of transfer standard

Frequency counter is designed to measure the frequency signal. Used to calibrate, check and maintain signal generator devices. In this comparison frequency counter type CNT-91, serial number 201563 manufacturer Pendulum was used as an artifact (figure 2). INM MD is the reference laboratory where frequency counters are calibrated.

Table 1. Metrological characteristics of frequency counter.

Range	Resolution	Reference oscillator stability
0,001 Hz ÷ 300 MHz	12 digits with a measurement time of 1 s	5×10^{-11} (Rubidium)

Figure 2. Transfer standard frequency counter

Calibration method and instrumentation used

All laboratory measurements were performed by direct measurements in accordance with approved calibration procedures. According to an approved calibration procedure, each laboratory selected a calibration method, a formula for calculating measurements, and estimated the expanded uncertainty by multiplying the standard uncertainty by a coverage factor k = 2.

Auxiliary measuring instruments were used to measure the ambient conditions. The calibration report should be submitted to the actual environmental conditions during measurement.

Calculation of the reference values

The reference value is calculated based on formula 1 as the average between the value obtained by the pilot laboratory before transport of the standard and the value obtained after transport:

$$x_{ref} = \frac{x_{ref1}+x_{ref2}}{2} \qquad (1)$$

where:

x_{ref} - the reference value obtained by the pilot laboratory (INM MD);

x_{ref1} - the value obtained by the pilot laboratory before the standard was transported to UzNIM;

x_{ref2}- value obtained by the pilot laboratory after transportation of the standard from UzNIM

3. Results and Discussion

The results are presented in table (table 2 and 3) form at each calibration point. Nominal frequency values 10 kHz, 100 kHz, 1 MHz, 10 MHz, 25 MHz, 50 MHz, 100 MHz, 200 MHz, 300 MHz were chosen for the calibration measurement point.

Table 2. INM MD calibration results frequency counter

Nominal value	Measured value	Frequency counter error	Expanded Uncertainty*
kHz			
10	9,9999951	-8,98E-06	1,15E-07
100	99,999950	-9,23E-05	1,15E-06
MHz			
1	0,9999995	-9,25E-07	1,15E-08
10	9,9999949	-9,22E-06	1,16E-07
25	24,999987	-2,29E-05	2,57E-07
50	49,999975	-4,51E-05	5,03E-07
100	99,999998	-1,72E-06	1,20E-06
200	199,99999	-2,47E-06	1,20E-06
300	299,99999	-3,72E-06	1,20E-06

Table 3. UzNIM calibration results frequency counter.

Nominal value	Measured value	Frequency counter error	Expanded Uncertainty*
kHz			
10	9,999999	8,15E-07	1,73E-05
100	99,99992	-8,08E-05	3,80E-05
MHz			
1	0,9999991	-8,65E-07	1,00E-07
10	9,9999907	-9,34E-06	1,00E-07
25	24,999977	-2,28E-05	1,05E-07
50	49,999955	-4,50E-05	1,00E-07
100	99,999998	-1,89E-06	1,00E-07
200	199,99999	-2,66E-06	1,03E-07
300	299,99999	-4,45E-06	1,01E-07

*Expanded uncertainty corresponding to the coverage probability of approximately 95 %.

Evaluation of comparative measurements

To compare the results, the |En| value will be calculated. This value represents the deviation between the results of measurements by the pilot laboratory and the laboratory of the participant, taking into account the uncertainty of the measurement results.

$$E_n = \frac{|x_{lab}-x_{ref}|}{\sqrt{U_{lab}^2+U_{ref}^2}} \qquad (2)$$

where:

x_{lab} - The value for laboratory of UzNIM;

x_{ref} - The reference value for the pilot laboratory (INM MD);

U_{lab} - Calibration expanded uncertainty of the UzNIM;

U_{ref} - Expanded uncertainty of the pilot laboratory (INM MD).

This value represents the deviation between the measuring results of the participating laboratory and the pilot laboratory under consideration of the measuring uncertainty. For acceptable measurements the value of |En| must be less than 1.

The determined |En| - values of the comparison measurement are ≤ 1 that means the measurement result of

INM MD and UzNIM agree to within the reported expanded uncertainties. Evaluation results are indicated in Figure 3 and Table 4.

CONCLUSION

To sup up, the laboratories participating in the bilateral comparisons have demonstrated their competence and capabilities in the field of frequency counter calibration, and their results are considered positive. This result proves that both laboratories frequency counter calibration method was validated based on ISO/IEC 17043 standard and they can use this calibration method further.

References

[1]Durgut, Yasin (2021/09/30) "Inter-laboratory Comparisons and Their Roles in Accreditation" 10.31590/ejosat.1001957, European Journal of Science and Technology.

[2] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories.

[3] ISO/IEC 17043:2023 Conformity assessment General requirements for proficiency testing.

[4] Flavio Galliana1, Pier Paolo Capra, Roberto Cerri, Vincenzo D'Elia, Enrico Gasparotto, Luca Roncaglione Tet, Marco Del Moro and Alessandro Cozzani. "Inter-laboratory measurement comparison between INRIM and ESA on electrical quantities" 18th International Congress of Metrology, 07005 (2017), DOI: 10.1051/metrology/201707005.

[5] National Institute of Metrology (NIM) https://inm.md/eng.

[6] Uzbek National Institute of Metrology (UzNIM) https://www.nim.uz/eng.

[7] Final Report of bilateral inter-laboratory comparison Comparison of calibration results for frequency counter MD/096/23.

Table 4. Comparative calibration results for frequency signal measurement between INM MD and UzNIM and En factor calculation

Nominal value	INM MD			UzNIM			Factor |En|
	Measured value	Frequency counter error	Expanded Uncertainty*	Measured value	Frequency counter error	Expanded Uncertainty*	
kHz				**kHz**			
10	9,9999951	-8,98E-06	1,15E-07	9,999999	8,15E-07	1,73E-05	0,57
100	99,999950	-9,23E-05	1,15E-06	99,99992	-8,08E-05	3,80E-05	0,30
MHz				**MHz**			
1	0,99999950	-9,25E-07	1,15E-08	0,9999991	-8,65E-07	1,00E-07	0,60
10	9,9999950	-9,22E-06	1,16E-07	9,9999907	-9,34E-06	1,00E-07	0,78
25	24,9999876	-2,29E-05	2,57E-07	24,9999772	-2,28E-05	1,05E-07	0,35
50	49,9999758	-4,51E-05	5,03E-07	49,9999550	-4,50E-05	1,00E-07	0,24
100	99,9999988	-1,72E-06	1,20E-06	99,9999982	-1,89E-06	1,00E-07	0,14
200	199,9999976	-2,47E-06	1,20E-06	199,9999973	-2,66E-06	1,03E-07	0,15
300	299,9999964	-3,72E-06	1,20E-06	299,9999954	-4,45E-06	1,01E-07	0,60

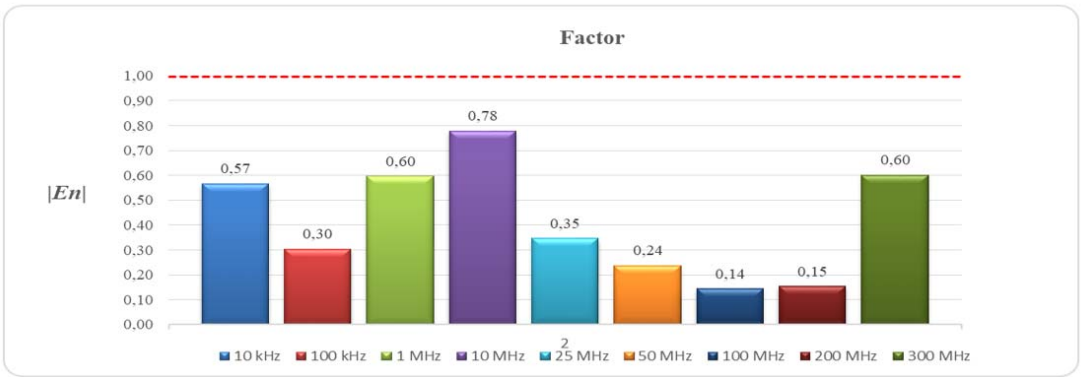

Figure 3. Results of E_n factor in comparison between of INM MD and UzNIM for frequency value measurements.