Supplementary bilateral comparison of pulse voltage COOMET 710/RU-a/16 (COOMET.EM-S23)

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Abstract – This supplementary bilateral comparison of pulse voltage is intended to compare the Russian State primary standard of impulse electrical voltage and the reference standard of impulse electrical voltage of the Republic of Belarus. Its description and measurement results are presented below.

Index Terms – Comparisons, standard uncertainty, measurement, impulse electrical voltage, front duration, instantaneous values of impulse electrical voltage, pulse voltage, rise time.

This supplementary bilateral comparison of primary standards of impulse electrical voltage was conducted on the initiative of the following National Metrology Institutes (NMIs): VNIIFTRI (Russian Federation) and BelGIM (Republic of Belarus). The comparison was carried out under COOMET project 710/RU-a/16 "Carrying out supplementary bilateral comparison of pulse voltage" (COOMET.EM-S23). The comparison involved national standards: the Russian State primary standard unit of the impulse electrical voltage (GET 182-2010) and the reference standard of the impulse electrical voltage of BelGIM (BelGIM standard). VNIIFTRI and BelGIM implement the independent reproduction of the pulse voltage unit using the primary standard GET 182-2010 and BelGIM standard.

The step pulse generator TMG030010SN11-M1 was used as a traveling standard. The values of the impulse electrical voltage, produced by means of the

traveling standard, were measured by the national standards. The purpose of the comparison was to confirm confidence in the measurement results and calibration certificates, issued by the NMIs in the field of impulse electrical voltage measurements, and to confirm their calibration and measurement capabilities (CMCs) in this area.

The measurements were carried out under the supervision of VNIIFTRI, which acted as a pilot laboratory (measurement start: 10/2017). Measurements of impulse electrical voltage produced by the traveling standard were carried out in the following order:

first - measurements of impulse electrical voltage on the GET 182-2010,
then - on the BelGIM standard
and finally - again on the GET 182-2010.

The participants of the comparison measured the instantaneous values of the pulse voltage produced by the traveling standard in the time interval of 20-98 ps (the time interval was counted after the time interval of 20 ps from the time point of the pulse front corresponding to ½ of the pulse amplitude), and also determined the front duration (this is the time needed for the signal to rise from 10 % to 90 % of the pulse amplitude value) and expanded uncertainties of the measurement results [1, 2]. When measuring instantaneous values of the pulse voltage, an attenuator was used to limit the amplitude of the traveling standard signal (up to approximately 650 mV) and; in this case, the signal from the output of the traveling standard was supplied to the oscilloscope input via adapters SM3077, SM3008 and attenuator SA50-20. The measured signal was normalized to the pulse voltage amplitude (this is the average value of the instantaneous values of the pulse voltage generated by the traveling standard over a time interval of 20-98 ps), while special methods of mathematical processing of the measured information were used to reduce the error in reproducing the unit of pulsed electrical voltage due to jitter and limited bandwidth of the oscilloscope [3, 4].

The participants provided results with associated measurement uncertainties and uncertainty budget. The $x_{GET(i)}$ values (in Table 2) represent the average value of the measurement results made on GET 182-2010 before and after measurements performed on the BelGIM standard (thus the instability of the traveling standard was significantly reduced).

In accordance with the «Guideline on COOMET supplementary comparison evaluation» (COOMET R/GM/19), the reference value of the measured front duration τ_{ref} and its extended uncertainty $U_{\tau ref}$ (for confidence level P = 95% with coverage coefficient k = 2) were calculated by formulas (1) and (2), respectively.

$$\tau_{ref} = \frac{\tau_{GET}/U^2_{\tau GET} + \tau_{BelGIM}/U^2_{\tau BelGIM}}{1/u^2_{\tau GET} + 1/u^2_{\tau BelGIM}} \quad (1)$$

$$U_{\tau ref} = 2 \cdot \sqrt{\frac{1}{1/u^2_{\tau GET} + 1/u^2_{\tau BelGIM}}} \quad (2)$$

The results of the measurement of the front duration with GET 182-2010, τ_{GET}, with extended uncertainty $U\tau_{GET}$ (for confidence level P = 95% with coverage coefficient k = 2) and BelGIM standard, τ_{BelGIM}, with corresponding extended uncertainty $U_{\tau BelGIM}$ (for confidence level P = 95% with coverage coefficient k = 2) and the reference value τ_{ref} with extended uncertainty $U_{\tau ref}$ (for confidence level P = 95% with coverage coefficient k = 2) are shown in Table 1 and Figure 1.

Table 1 – The results of the measurement of the front duration

τ_{GET}, ps	$U_{\tau GET}$ (P = 95%, k = 2), ps	$\tau_{avgBelGIM}$, ps	$U_{\tau BelGIM}$ (P = 95%, k = 2), ps	τ_{ref}, ps	$U_{\tau ref}$ (P = 95%, k = 2), ps
31.24	1.14	30.90	1.12	31.07	0.80

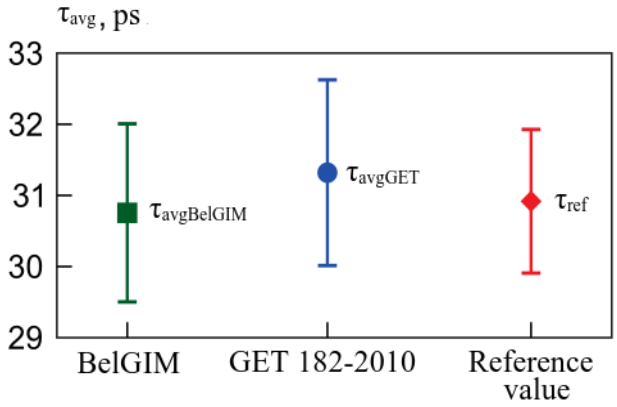

Figure 1 - The results of the measurement of the front duration

In accordance with COOMET R/GM/19, the value of the chi-squared value χ^2 was calculated by formula (3):

$$\chi^2 = \frac{(\tau_{GET}-\tau_{ref})^2}{u^2_{\tau GET}} + \frac{(\tau_{BelGIM}-\tau_{ref})^2}{u^2_{\tau BelGIM}} \quad (3)$$

The chi-squared value χ^2 = 0.18 does not exceed the critical value χ^2_{cr} = 3.84 (for P = 95% for bilateral comparisons).

In accordance with COOMET R/GM/19, the reference values for the instantaneous voltage values, $x_{ref(i)}$, with extended uncertainties $Ux_{ref(i)}$ (for confidence level P = 95% with coverage coefficient k = 2) and the chi-squared values $\chi^2_{(i)}$ were calculated by formulas (4), (5) and (6), respectively.

$$x_{ref(i)} = \frac{x_{GET(i)}/u^2_{xGET(i)} + x_{BelGIM(i)}/u^2_{xBelGIM(i)}}{1/u^2_{xGET(i)} + 1/u^2_{xBelGIM(i)}} \quad (4)$$

$$U_{xref(i)} = 2 \cdot \sqrt{\frac{1}{1/u^2_{xGET(i)} + 1/u^2_{xBelGIM(i)}}} \quad (5)$$

$$\chi^2_{(i)} = \frac{(x_{GET(i)}-x_{ref(i)})^2}{u^2_{xGET(i)}} + \frac{(x_{BelGIM(i)}-x_{ref(i)})^2}{u^2_{xBelGIM(i)}} \quad (6)$$

The results of the measurements of instantaneous values of impulse electric voltage using GET 182-2010, $x_{GET(i)}$, with extended uncertainties $Ux_{GET(i)}$ (for confidence level P = 95% with coverage coefficient k = 2), using BelGIM standard $x_{BelGIM(i)}$ with extended uncertainties $Ux_{BelGIM(i)}$ (for confidence level P = 95% with coverage coefficient k = 2), the reference values $x_{ref(i)}$ with extended uncertainties $Ux_{ref(i)}$ (for confidence level P = 95% with coverage coefficient k = 2) and the corresponding chi-squared values $\chi^2_{(i)}$ in the time interval $\Delta_{t(i)}$ = (20, ..., 98) ps (for i = 1, ..., 40) are shown in Table 2 and in Figure 2.

Table 2 - The results of measurements of instantaneous values of impulse electrical voltage, relative to the nominal peak voltage of about 650 mV. The $x_{GET(i)}$ values represent the average value of the measurement results made on GET 182-2010 before and after measurements, performed on the BelGIM standard.

i	$\Delta_{t(i)}$, ps	$x_{GET(i)}$, V/V	$Ux_{GET(i)}$, V/V	$x_{BelGIM(i)}$, V/V	$Ux_{BelGIM(i)}$, V/V	$x_{ref(i)}$, V/V	$Ux_{ref(i)}$, V/V	$\chi^2_{(i)}$
1	20	1,031	0,012	1,024	0,024	1,030	0,011	0,27
2	22	1,036	0,012	1,024	0,024	1,034	0,011	0,80
3	24	1,031	0,012	1,015	0,024	1,028	0,011	1,42
4	26	1,021	0,012	1,001	0,024	1,017	0,011	2,22
5	28	1,007	0,012	0,984	0,024	1,002	0,011	2,94
6	30	0,993	0,012	0,967	0,024	0,988	0,011	3,76
7	32	0,979	0,012	0,953	0,024	0,974	0,011	3,76
8	34	0,968	0,012	0,942	0,024	0,963	0,011	3,76
9	36	0,962	0,012	0,936	0,024	0,957	0,011	3,76
10	38	0,96	0,012	0,936	0,024	0,955	0,011	3,20
11	40	0,962	0,012	0,94	0,024	0,958	0,011	2,69
12	42	0,968	0,012	0,948	0,024	0,964	0,011	2,22
13	44	0,977	0,012	0,959	0,024	0,973	0,011	1,80
14	46	0,987	0,012	0,971	0,024	0,984	0,011	1,42
15	48	0,998	0,012	0,983	0,024	0,995	0,011	1,25
16	50	1,009	0,012	0,994	0,024	1,006	0,011	1,25
17	52	1,018	0,012	1,003	0,024	1,015	0,011	1,25
18	54	1,025	0,012	1,010	0,024	1,022	0,011	1,25
19	56	1,029	0,012	1,015	0,024	1,026	0,011	1,09
20	58	1,032	0,012	1,017	0,024	1,029	0,011	1,25
21	60	1,033	0,012	1,017	0,024	1,030	0,011	1,42
22	62	1,032	0,012	1,016	0,024	1,029	0,011	1,42

i	$\Delta_{t(i)}$, ps	$x_{GET(i)}$, V/V	$Ux_{GET(i)}$, V/V	$x_{BelGIM(i)}$, V/V	$Ux_{BelGIM(i)}$, V/V	$x_{ref(i)}$, V/V	$Ux_{ref(i)}$, V/V	$\chi^2_{(i)}$
23	64	1,03	0,012	1,013	0,024	1,027	0,011	1,61
24	66	1,027	0,012	1,01	0,024	1,024	0,011	1,61
25	68	1,024	0,012	1,007	0,024	1,021	0,011	1,61
26	70	1,021	0,012	1,005	0,024	1,018	0,011	1,42
27	72	1,019	0,012	1,002	0,024	1,016	0,011	1,61
28	74	1,017	0,012	1,001	0,024	1,014	0,011	1,42
29	76	1,016	0,012	1,000	0,024	1,013	0,011	1,42
30	78	1,015	0,012	1,000	0,024	1,012	0,011	1,25
31	80	1,015	0,012	1,001	0,024	1,012	0,011	1,09
32	82	1,015	0,012	1,002	0,024	1,012	0,011	0,94
33	84	1,015	0,012	1,003	0,024	1,013	0,011	0,80
34	86	1,015	0,012	1,004	0,024	1,013	0,011	0,67
35	88	1,014	0,012	1,005	0,024	1,012	0,011	0,45
36	90	1,014	0,012	1,005	0,024	1,012	0,011	0,45
37	92	1,013	0,012	1,004	0,024	1,011	0,011	0,45
38	94	1,012	0,012	1,002	0,024	1,010	0,011	0,56
39	96	1,010	0,012	1,000	0,024	1,008	0,011	0,56
40	98	1,008	0,012	0,997	0,024	1,006	0,011	0,67

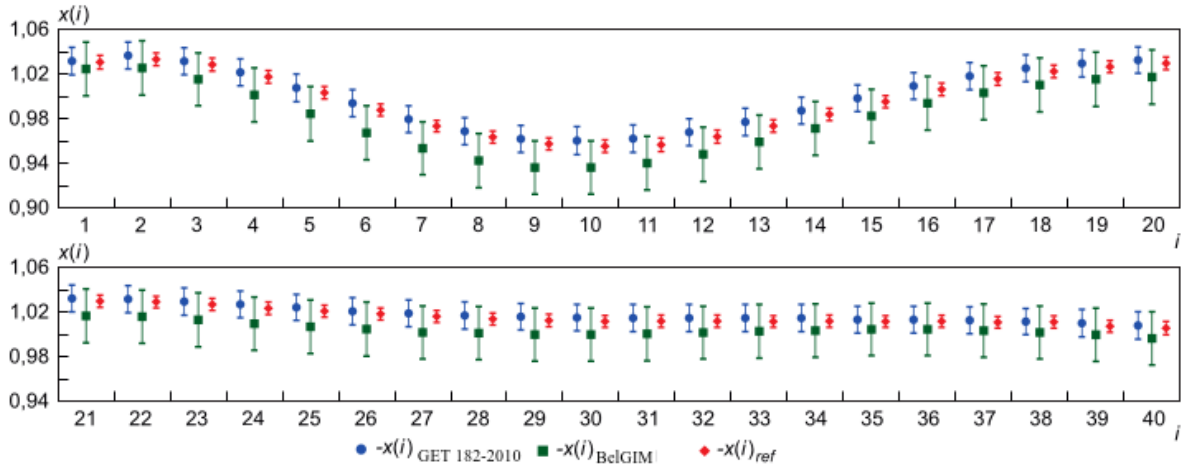

Figure 2 - The results of measurement instantaneous values of the impulse electrical voltage

None of the chi-squared values $\chi^2_{(i)}$ (for i = 1, ..., 40) exceeds the critical value χ^2_{cr} = 3.84 (for P = 95% for bilateral comparisons).

All data presented by the NMIs during the measurements, calculations and processing of the results of the comparisons are recognized as consistent and confirm the uncertainties for values of impulse electrical voltage unit for VNIIFTRI and BelGIM declared during the present comparisons under the COOMET project.

This is also evidence for the corresponding calibration and measurement capabilities (CMCs) for those values of impulse electrical voltage unit measured by the national standards.

References

1. Manevich V. Z., Selin L. N., Measurement Techniques. 2012. vol. 54. no. 12. pp. 1319–1326. https://doi.org/10.1007/s11018-012-9890-5

2. Gans W.L., Proc. IEEE. 1986. vol. 74. no. 1. pp. 86–90. https://doi.org/10.1109/PROC.1986.13408

3. Novikov N. Yu., Kleopin A. V., Measurement Techniques. 2008. vol. 51. no. 8. pp. 893–895. https://doi.org/10.1007/s11018-008-9126-x

4. Andrews J. R., Removing Jitter From Picosecond Pulse Measurements. Boulder Picosecond Pulse Labs. 2009. Appl. Note 23. 2009.