Progress Report to CCEM

(The 30th meeting of the CCEM, March 2017)

Electrical and magnetic measurements

Submitted by A. Katkov, VNIIM (St. Petersburg, Russia)
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DC voltage (A. Katkov)

The primary voltage standard of VNIIM based on Josephson effect consists of the laboratory-made devices that can use 1 V and 10 V SIS and SINIS arrays made in PTB, Germany, and 1 V SIS array made in Russia.

VNIIM used 10 V transportable Josephson standards for a COOMET key comparison of national voltage standards..

VNIIM was the pilot laboratory in the bilateral key comparison with (COOMET project 542/RU/11). The final result showed a very good agreement.

VNIIM was a collaborator in the Q-WAVE project, covering the following tasks:
- model practical sampling measurement methods;
- analyse experimental measurement set-up;
- suggest testing methods to investigate possible error sources.

VNIIM developing a new 10 V Programmable Josephson Voltage Standard.
In the course of this work, cryoprobe, microwave generator and software are designed.

VNIIM has started collaboration in the QuADC project.

Publications

Final Report on Key Comparison COOMET.EM.BIPM-K10.b - Comparison of 10 V Josephson Voltage Standards. COOMET 542/RU/11. // Metrologia (Technical Supplement 2015) 52 01024
A. S. Katkov, P. A. Chernyaev. Key Comparison of the Volt Standards of the Russian Federation and the Republic of Belarus, Using a Quantum Comparison Standard. // Measurement Techniques, 2016, Vol. 59, Issue 4, pp 444–448. DOI: 10.1007/s11018-016-0987-0
A. S. Katkov, V. V. Gerasimenko. Current State and Future Trends in the Development of Standards Based on the Josephson Effect. // Measurement Techniques, November 2016, Volume 59, Issue 8, pp 861–865
A. Katkov, V. Lovtsus, R. Behr. Portable Josephson voltage reference standard. // Conference digest CPEM 2016, 2 p. DOI: 10.1109/CPEM.2016.7540664

Voltage Standard Using Josephson Junctions Cooled to 77 K (a_klushin@ipmras.ru)

A commercial dc voltage standard with output voltages U_{HTS} from 0.1 V to 10 V using high temperature superconductor (HTS) arrays of Josephson junctions cooled to 77 K was characterized. This voltage standard also includes a small size cryocooler, a compact mm wave synthesizer with the frequency bandwidth of 69-78 GHz, a rubidium frequency standard and a nanovoltmeter. HTS arrays with increased current limit up to 0.4 mA and the voltage divider with a high stability of the divider coefficients enable stable and reproducible automated calibration of the new HTS standard. The direct comparison of U_{HTS} against the voltage generated on an array of niobium Josephson junctions cooled to 4.2 K shows the agreement of voltages at 1 V level with a Type A uncertainty equal to a few parts in 10^8.

Publications

E. E. Pestov, M. Yu. Levitchev, A. M. Klushin. On the Cryocooler-Based Cooling of Josephson Microchips Fabricated from Cuprate Superconductors for Use in Voltage Standards. // Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques, 2016, Vol. 10, No. 2, P. 302–306.

A. M. Klushin, E. E. Pestov, M. A. Galin, M. Yu. Levichev. High-temperature superconductor Josephson junctions for voltage standards. // Physics of the Solid State. November 2016, Volume 58, Issue 11, pp 2196–2202.

S. K. Khorshev, A. I. Pashkovsky, N. V. Rogozhkina, M. Yu. Levichev, E. E. Pestov, A. S. Katkov, R. Behr, J. Kohlmann, A. M. Klushin. Accuracy of the New Voltage Standard Using Josephson Junctions Cooled to 77 K. // Conference Digest CPEM 2016, 2 p. DOI: 10.1109/CPEM.2016.7540701

DC current (O. Pavlov)

VNIIM maintains and develops the state primary standard of dc current in the range of $1 \cdot 10^{-16}$ A to 1 A. VNIIM uses a unique transportable standard of dc current in the range of $1 \cdot 10^{-15}$ A to $1 \cdot 10^{-9}$ A.

Publications

A. S. Katkov, I. V. Korotkova, V. E. Lovtsyus, O. M. Pavlov, V. I. Shevtsov. The Standard Base of the All-Russia Research Institute of Metrology for Measuring Small DC Currents in the 10^{-16}–10^{-9} A Range. // Measurement Techniques, 2015, Vol. 57, No 11, pp. 1279-1281.

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DC Voltage electrostatic field (O. Pavlov)

VNIIM maintains and develops the State standard for the unit of the electrostatic field. The range of the electrostatic field in free space is ± 200 kV/m. The range of electrostatic potential is ± 30 kV. Limits of relative error of reproduction set point electrostatic field strength is 1.5%. Limits of a relative error of reproduction set point charged surface potential is 0.4%.

AC Voltage (V.I. Shevtsov)

VNIIM maintains and develops the State primary ac voltage standard consisting of:

- special primary standard for the unit of electrical voltage in the frequency range from 10 to $3 \cdot 10^7$ Hz at voltage from 0.1 to 1000 V;
- special primary standard for the unit of electrical voltage in the frequency range from $3 \cdot 10^7$ to $2 \cdot 10^9$ Hz at voltage from 0.1 to 10 V.

A calibration manual for the new secondary AC voltage standard in the frequency range from $3 \cdot 10^7$ to $2 \cdot 10^9$ Hz for the voltage from 0.1 to 3 V was drawn up.

Publications

Telitchenko G.P., Shevtsov V.I. The third generation of the State Primary Special Standard for the electric current unit - GET 88-2014. Legal and Applied Metrology. 2015. T. 4. № 137. P. 16-19 (in Russian).

Gurevich M.L., Cheremokhin A.V., Telitchenko G.P., Shevtsov V.I. A new precision measuring voltage thermo comparator of PNTE-36 kit and results of their investigation. Legal and applied metrology. 2015. T. 1. № 134. P. 7-14 (in Russian).

AC current (V.I. Shevtsov)

VNIIM maintains and develops the State Primary AC current Standard in the frequency range of 20 Hz to $1 \cdot 10^6$ Hz. It consists of a unique set of thermo-converters that directly convert the AC current up to 20 A. AC current shunts parameters were investigated in the range up to 100 A at frequencies up to 100 kHz.

Publications

Telitchenko G.P., Shevtsov V.I. National Primary Special Standard (GET 88-2014) for the unit of electric current at frequencies of 20 to $1 \cdot 10^6$ Hz. Measurement Techniques. 2015. T. 58. № 9. P. 937-941.

Impedance (Yu.P. Semenov)

VNIIM participates in the key comparison CCEM K2 of high-valued resistance standards.
VNIIM participates in the key comparison CCEM K4 of capacitance standards. The measurement will be accomplished by March 31, 2017. Currently the documents necessary for transit of the Russian state border and shipment to BIPM are prepared.

R&D of traveling inductance standard of 100 mH suitable for interlaboratory and key comparisons is carried out. Preliminary results have showed the possibility of the standard implementation with the following characteristics:

- 4TP connection;
- small-size (mass less than 1 kg);
- Q-factor as for GR measure;
- temperature coefficient of inductance less than 15 ppm/K.

The measures are developed on the base of RC equivalents and inductive voltage dividers. Uncertainty less than few ppm has been assessed during comparison of the aforementioned measures with conventional inductance standards at frequencies of 1 and 1.6 kHz by means of a digital RLC-meter.

LF Power (g.b.gubler@vniim.ru)

VNIIM joined to the European EMPIR project “TracePQM”: Traceability routes for Power Quality Measurements” as a collaborator in 2016. VNIIM investigates signal-processing techniques for non-coherent sampling.

VNIIM developed methods for calibration of non-conventional instrument transformers with 61850-9-2 output protocol and stand-alone merging units. The designed calibration system was used to characterize a few reference-level (0,01 % in-phase, 80 mkrad quadrature errors) calibration setups for industrial partners.

VNIIM continues carrying out joint work with NMIA to establish the traceability in measurements of harmonics parameters for power standards.

VNIIM has been participating in the following comparisons:
AC power at 50/60 Hz: APMP.EM-K5.1; CCEM-K5; COOMET.EM-K5

AC power harmonics: CCEM-K13.

Publications

G.Gubler, I.Budovsky. Comparison of two realizations of a power standard. // 2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Year: 2016 Pages: 1-2, DOI: 10.1109/CPEM.2016.7540542

G.Gubler, N.Alekseeva. Making low level AC voltage measurements with DVM. // 2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Year: 2016 Pages: 1-2, DOI: 10.1109/CPEM.2016.7540554

A. Katkov, G. Gubler, J. Lee, R. Behr, and J. Nissilä. Influence of Harmonics on AC Measurements Using a Quantum Voltmeter. // Conference Digest CPEM 2014. Rio de Janeiro. 2014. P. 526 – 527.

Magnetic measurements (V.Ya.Shifrin@vniim.ru)

Metrology service for magnetic measurements in the Russian Federation functions on the basis of the State primary standard (GET 12-2011) for the units of magnetic flux density (MFD), magnetic flux, magnetic moment and a magnetic flux density gradient.

The State primary standard makes it possible to realize dc MFD measurements and to disseminate the MFD unit in the range from $1\cdot10^{-6}$ to $1\cdot10^{-3}$ T with the total standard relative uncertainty from $3\cdot10^{-5}$ to $2\cdot10^{-7}$.

VNIIM was the pilot laboratory in the first international comparison of MFD standards in the geomagnetic range (APMP.EM-S14), in which participated nine countries..

The results of this comparison will provide for extending the metrology service to the range of $1\cdot10^{-6}$ nT to down to $1\cdot10^{-8}$ nT in the realization and dissemination of the dc MFD unit, which is especially important for the space and magnetic screen investigations and for specific medical and other applications.

The standard deviation of the MFD realization was experimentally determined by the modified measuring system as not exceeding 0,1 nT in the range of $\pm$ 1000 nT.

The method and technics of this measuring system were realized on the basis of expansion of functionalities of the standard three-component DC magnetic flux density comparator and the standard helium-cesium magnetometer that are parts of the State primary standard.

Publications

V. Ya. Shifrin, V. N. Khorev, V. N. Kalabin, S. L. Voronov, A. E. Shilov. The State Primary Standard for the units of magnetic induction, magnetic flux, magnetic moment, and magnetic induction gradient, Measurement Techniques, 2012, Vol. 55, Issue 7, pp. 739-744. doi:10.1007/s11018-012-0031-y

V. Ya Shifrin, V N Khorev, J Rasson and Po Gyu Park. International comparisons to establish the traceability in the global network of geomagnetic observatories to SI units, 2014, Metrologia, 51 01015 doi:10.1088/0026-1394/51/1A/01015

V Ya Shifrin, V N Kalabin, D.I. Belyakov. Development of a Reference Framework for the Measurement of Magnetic Induction of a Constant Field in the Range of Geomagnetic and the Hypo-Geomagnetic Values”), Measurement Techniques, 59(9), 975-978, DOI 10.1007/s11018-016-1078-y, Springer 2016

Pulse Electromagnetic Fields and Currents (VNIIOFI, Moscow, Russia)

Oleg V. Mikheev, mikhv-m12@vniiofi.ru

The State primary standard for the pulse electric and magnetic field intensity units with a pulse rise time over the range from 0.1 up to 100 ns. The standard facility consists of two ultra-wideband TEM-cells excited by pulse voltage generators. The first of them has two operating volumes (0.24×0.5×0.5 m and 0.48×1.0×1.0 m). This cell is excited by pulse generators with energy storages based on low-inductive capacitor (3 μF, 50 kV) and transmission line sections. Storages are switched on load with nitrogen-filled spark gap. Exponential and step pulses are produced. Minimal pulse rise time is 1.0 ns, exponential pulse fall time is 150 μs, maximal electric field intensity is 200 kV/m. The second cell is a two-wired common-mode excited transmission line inside the shield. Effective width of gap between electrodes is 74 mm. A step pulse generator based on solid-state fast switch (FID Technology GmbH) excites this cell. The minimal electric field pulse rise time does not exceed 100 ps at a 320 kV/m field intensity. The expanded uncertainties (k = 3) are 2 % and 7.5 % in exponential and step pulse operation modes, respectively.

Publications

Sakharov K.Yu. et al. The Metrological Support for Measurements of the Parameters of Intense Pulsed Electromagnetic Fields in the Subnanosecond Range. // Meas. Techn. (2015) 58:1023.

Sakharov K.Yu. et al. Metrological Assurance of Devices Intended to Measure the Parameters of Pulsed Electric and Magnetic Fields of Natural and Artificial Origin. // Meas.Techn. (2016) 59:160.

The State primary standard of the pulse electric and magnetic field intensity units with a pulse rise time over the range from 10 ps up to 100 ps. The standard facility includes an ultra-wideband monocone antenna and voltage pulse generators with a pulse rise time in the picosecond range. Monocone impedance is 50 Ohm, cone base diameter is 1 m and ground plane diameter is 2 m. Generators produce voltage drop pulses with a rise time not exceeding 5 ps with an amplitude of 10 to 20 V. The electric field intensity at the operation volume of antenna is 30 V/m, when the pulse rise time does not exceed 10 ps. IPPL-L measuring transducers based on microstrip line are used as a comparator transferrin the transfer of the unit. The transducer with a coaxial cable line is tuned in such a way that the output pulse should be equivalent to E-field pulse without integration. The Tektronix CSA8000B sampling oscilloscope is used for the transducer output pulse registration. The expanded uncertainty is 3.6 % (k = 3).

Publications

Sakharov, K.Y., Podosenov, S.A., Turkin, V.A. et al. Use of the Method of Predetermined Currents to Calculate the Parameters of Pulsed Electromagnetic Fields with a Rise Time Up to 10 psec in the Time Domain. // Meas. Tech. (2016) 58: 1261.

Alexander V. Sukhov, sukhov@vniiofi.ru

The state primary standard of the lightning discharge pulse current unit has the range from 1 up to 100 kA. The standard facility includes a pulse generator with the capacitive storage of 3 μF, 50 kV, a controllable nitrogen-filled spark gap switch, a discharge resistor to limit the current, a pulse current transformer and output terminals. The Facility is intended for calibrations of several types of current transducers,, e.g. shunts, Rogowski coils, and optoelectronic current sensors. The facility has two operation modes. In the first mode storage discharges directly to output terminals through the discharge resistor. An exponential pulse has I_{max} = 1÷8 kA and τ_r/t_p = 0.15/10 μs. In the second mode storage discharges through transformer and exponential pulse with I_{max} = 6÷100 kA and τ_r/t_p = 10/40 μs is produced. Thus, it is possible to determine both the sensor transfer characteristic rise time and its measurement range. The expanded uncertainty in the realization of the unit is 4.5 % (k = 3). In the future, we are going to decrease the pulse rise time to cover the electrostatic discharge current time range.

Publications

Sakharov, K.Yu. et al. Metrological Assurance of Measurements of Pulsed Lightning-Strike Currents. // Meas. Tech. (2015) 58:1266.