Progress Report to CCEM

(The 31th meeting of the CCEM, March 2019)

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 has 10 V transportable Josephson standard for a key comparison of national voltage standards.

VNIIM developed a 10 V Programmable Josephson Voltage Standard based on Supracon (Germany) array.

In the course of this work, cryoprobe, microwave generator and software are designed.

VNIIM is a collaborator in the QuADC project. With PTB collaboration the sinusoidal voltage with rms of 20 mV in the frequency range from 100 Hz up to 1.75 kHz was obtained. The sinusoidal signal with amplitude from 100 nV to 100 µV in the frequency range from 100 to 200 Hz was used for AC calibration of an instrument 3458A.

Publications

A. S. Katkov, V. E. Lovtsyus, A. I. Bykov, V. I. Shevtsov, G. V. Novoderezhkin. “Reproduction of the Volt Based on SIS- and SNS-type Josephson Junctions.” Measurement Techniques. September 2017, Volume 60, Issue 6, pp 589–593.

A. Stepanov, A. Katkov and A. Chunovkina, "Evaluation of Zener standard drifts", CPEM 2018 Conf. Digest, pp. 193-194, July 2018

A. Katkov, G. Gubler, and V. Shevtsov, “VNIIM 10 V Programmable Josephson Voltage Standard,” CPEM 2018 Conf. Digest, pp. 637-638, July 2018.

R. Behr, A. Katkov, J. Lee, S. Bauer, O. Kieler, and L. Palafox, "Frequency range extension of the AC quantum voltmeter", CPEM 2018 Conf. Digest, pp. 984-985, July 2018.

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

O.M. Pavlov, V.I. Shevtsov. “On the test results for the approval of the type of leakage current sensor.” Digest of materials of the 72nd All-Russian Scientific and Technical Conference dedicated to the Day of Radio, St. Petersburg, 2017. p. 521-522 (in Russian).

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 up to ± 1000 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 0.6%.

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.

Publications

M.L. Gurevich, A.V. Cheremokhin, V.I. Shevtsov, G.P. Telitchenko. "New precision sets of voltage thermal converters PNTE-37 and their test results." Legal and Applied Metrology. 2018, N 1, P. 11-15 (in Russian).

M.L. Gurevich, V.I. Shevtsov. "Domestic electro-thermal and diode-detector technologies for alternating voltage meters." Legal and Applied Metrology. 2018, N 3, P. 30-37 (in Russian).

M.L. Gurevich, A.V. Cheremokhin, V.Yu. Maksimov, V.I. Shevtsov. "Electrothermal current AC-DC current comparators for secondary speakers electric current measurement standards." Legal and Applied Metrology. 2018, N 4, P. 27-32 (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.

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

The new project was started to build up reference three phase system for calibration of Phasor Measurement Units and Power quality analyzers.

New reference setup for currents both up to 1000 A and 2500 Hz was developed in cooperation with UNIIM (Ural Scientific and Research Institute for Metrology). It forms basis for calibration of instruments current transformers under distorted signals conditions.

Comparisons

VNIIM has been participating in the following comparisons:

AC power at 50/60 Hz: APMP.EM-K5.1; COOMET.EM-K5;

Ongoing comparisons

AC power at 50/60 Hz: CCEM-K5.

AC power harmonics: CCEM-K13.

Publications

G. Gubler. "Extension of a Waveform Reconstruction Algorithm for a DVM with an Integrating ADC." Conference on Precision Electromagnetic Measurements (CPEM 2018) DOI: 10.1109/CPEM.2018.8500991

I. Budovsky, Mun-Seog Kim, S. Solve, G.B. Gubler. "Comparison of PNS and Thermal Converter AC Voltage Measurements Between BIPM and NMIA Using a Sampling Voltmeter." Conference on Precision Electromagnetic Measurements (CPEM 2018) DOI: 10.1109/CPEM.2018.8501093

D. Georgakopoulos,I. Budovsky, S. P. Benz, G. Gubler. "Josephson Arbitrary Waveform Synthesizer as a Reference Standard for the Measurement of the Phase of Harmonics in Distorted Signals." Conference on Precision Electromagnetic Measurements (CPEM 2018) DOI: 10.1109/CPEM.2018.8501223

A. Katkov, V. Shevtsov, G. Gubler. "VNIIM 10 V Programmable Josephson Voltage Standard." Conference on Precision Electromagnetic Measurements (CPEM 2018) DOI: 10.1109/CPEM.2018.8500892

Magnetic measurements (V. Shifrin)

VNIIM directed to research aimed at expanding functionality of state (RF) standard of the magnetic units GET 12-2011 in the part of transition magnetic flux density unit from range of “meddle” fields ($1 \cdot 10^{-6}$ – $1 \cdot 10^{-3}$ T) to the ranges of “low” ($1 \cdot 10^{-8}$ – $1 \cdot 10^{-6}$T) and “high” magnetic fields ($1 \cdot 10^{-3}$ – 1 T) and transmission of a magnetic flux unit to soft magnetic materials parameters.

The transported quantum comparator of a DC magnetic flux density (MFD) is created on the basis of realization two zone uniform field source and quantum system of automatic reproduction of nominal parameters of the of a MFD in geomagnetic range. The standard comparator expands functionalities of the state primary standard of MFD, magnetic flux, magnetic moment and MFD gradient GET 12-2011 and enables calibrations of precision magnetometers in the places of their mass application.

The quantum cesium atomic resonant magnetometer developed in D.I. Mendeleyev Institute for Metrology and working at the resolved structure of atoms of cesium and intended for expansion of range of reproduction and transfer of magnetic induction of the constant field of the state primary standard of GET12-2011 to area of "mean fields” is described. Results of the researches directed to reduction of an measurements uncertainty are given.

Publications

V.Y. Shifrin, D.I. Belyakov, D.D. Kosenkov, A.E. Shilov, "Development of a metrology base for area of measurements of a MFD for a "middle" and "high" DC magnetic fields”, 15th International Youth School-Conference Magnetic resonance and its applications”, St. Petersburg, Abstracts, April 2018.

V.Y. Shifrin, V.N Kalabin, D.I. Belyakov,"Method of reproduction of magnetic induction in the hypomagnetic range", patent for the invention, № 2650769, 17 April 2018.

Belyakov D.I., Khorev V.N., Shilov A.E., Shifrin, “Development of the standards base in the field of measurements of magnetic induction and magnetic flux” , Measurement Techniques T.60, № 12, pp.1199-1204, 2018.

Belyakov D.I., Kalabin V.N., Shifrin V.Y. “A reference quantum transported comparator of dc magnetic induction in the range 1–100 μT”, Measurement Techniques T.61, № 4, pp. 373-376, 2018.

V.Ya. Shifrin, A.E. Shilov, D.I. Belyakov, D.D. Kosenkov. "Application a quantum cesium magnetometer for the transmission of a magnetic flux density unit in the range of “mean fields” ($1 \cdot 10^{-3}$ – $2 \cdot 10^{-2}$ T),” Proceedings of the V international conference "laser, plasma research and technologies. LAPLACE-2019, Moscow, February, 2019.

RF power measurements (VNIIFTRI, Moscow, Russia)

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The state primary standard of the unit of RF power in the range of frequencies from 37.5 to 78.33 GHz.

From 2013 to 2016 a series of studies to improve its technical characteristics in the area of increasing measurement precision and expanding the frequency range from 37.50 to 78.33 GHz. It became possible to achieve these objectives through the realization of the following scientific results, which were obtained here for the first time:

1) new calorimetric bolometric power converters without any analogs in terms of efficiency of thermal substitution of the power of electromagnetic oscillations by the power of low-frequency current were developed;

2) the value of the systematic error of the standard was improved by taking into account the influence of the nonequivalence of substitution in calorimetric converters on the result was determined;

3) the efficiency of calorimetric power converters in the frequency range 37.5–78.33 GHz was measured by specially developed differential heat flux microcalorimeters used for 5.2 × 2.6 and 3.6 × 1.8 mm waveguides.

The expanded uncertainty is 0.6 % (k = 2).

Publications

V. A. Perepelkin, V. A. Semenov, I. P. Chirkov, A. V. Pavlov, M. V. Zhogun, and A. V. Koudel'nyi. "GET 167–2017 State primary standard of the unit of power of electromagnetic oscillatios in the range of frequencies from 37.5 to 78.33 GHz". Measurement Techniques, Vol. 60, No. 10, January, 2018, P. 973-978.

High AC and DC current (UNIIM, Ekaterinburg, Russia)

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The State Primary Standard for electric current (AC, DC) conversion coefficients units GET 152-2018 is responsible for the transfer of the electric current conversion coefficients units to current measurement transducers (metrological assurance of measurement transducers) in the Russian Federation.

In 2017, the primary standard was upgraded and now its measurement capabilities allow the unit to be transferred to DC and AC measurement transducers.

GET 152-2018 includes two standard systems:

1 Sinusoidal current standard system

Name of the characteristic	Value of the characteristic
Primary AC current range	from 0.5 to 50 000 A
Secondary AC current	1 or 5 A
Frequency	50 Hz
Value of the ratio error	from 0 to 0.02 A/A
Value of the phase displacement	from 0 to 0.02 rad
Expanded uncertainty of the ratio error	from 5 to 15 μA/A
Expanded uncertainty of the phase displacement	from 5 to 15 μrad

2 High direct current standard system

Name of the characteristic	Value of the characteristic
Range of DC currents	from 3.75 to 1,000 A
DC ratio error	1,000/1; 500/1; 300/1 A/A
Expanded uncertainty of the DC ratio error	from 15 to 60 μA/A

In 2014, a study of the effect of frequency variation on the characteristics of the primary standard at frequencies of 60 and 400 Hz was carried out.

Currently, the following works are carried out:

a) to expand the measurement capabilities of the primary standard to a frequency range from 40 to 2,500 Hz;

b) to expand the range of direct currents up to 10,000 A;

c) to ensure the metrological support of measurement transducers with digital output.

UNIIM has been participating in the following comparisons:

(2009-2011) COOMET.EM-S11 (COOMET 513/DE-a/10) Supplementary bilateral comparison of the measurement of current transformers (CTs). Pilot laboratory PTB;

(2016 - 2019) COOMET.EM-S22 (COOMET 681/RU-a/16) Supplementary Comparison of Instrument Current Transformers (CTs). Pilot laboratory UNIIM.

Publications

Enrico Mohns, Y Sychev and G Roeissle. Final report on COOMET.EM-S11: "Supplementary bilateral comparison of the measurement of current transformers between UNIIM and PTB," Metrologia, Vol. 51, Technical Supplement 01013.

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

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Two State primary standards are used for the pulse electric and magnetic field intensity units realization. The first one GET 148-2013 consists of two TEM-cell and set of high-voltage generators. The electric and magnetic field pulses with amplitude up to 300 kV/m (800 A/m) are produced. The pulse waveforms are double exponential and step functions with rise time from 0.1 up to 10 ns. The expanded uncertainty is 1 % in double exponential electric field pulse operation mode (k = 2). The standard facility GET 178-2016 is used for free-field E-field unit realization. It consists of 50-Ohm monocone antenna and set of voltage pulse generators with a pulse rise time in the picosecond range. The electric field intensity is 30 V/m, when the pulse rise time does not exceed 10 ps. The expanded uncertainty is 2.4 % (k = 2).

Two series of measurements were conducted in 2017-2018 within the Interlaboratory comparisons (COOMET project 682/RU/16) at KRISS (Korea) and NINT in collaboration with Tsinghua University (China). The pulse free-field E-field measurements were made in monocone systems. A microstrip IPPL-type E-field sensor was used as a transfer standard. The good agreement within the limits of 2 % was shown. The draft report is in progress.

VNIIOFI has been working on development of high pulse voltage unit realization mode in GET 148-2013 facility. The reference 50 kV voltage step pulses will be produced at the 50-Ohm load. The expected pulse rise time is no more than 100 ps.

Publications

Sakharov K. Yu. et al. “GET 148–2013: State Primary Special Standard of Units of Electric and Magnetic Pulse Field Strengths with Pulse Rise Time in the Range from 0.1 to 10.0 ns,” Measurement Techniques, vol. 61, n. 10, pp. 967-962, Jan. 2019. DOI: 10.1007-s11018-019-01534-z.

Sakharov K. Yu. et al. “GET 178–2016: State Primary Special Standard of the Units of the Intensity of Pulsed Electric and Magnetic Fields with Length of Pulse Front in the Range from 10 to 100 psec,” Measurement Techniques, vol. 61, n. 6, pp. 521–527, Sep. 2018. DOI: 10.1007/s11018-018-1461-y.

Sakharov K. Yu. et al. “Interlaboratory Standard for Calibrating the Primary Standards of the Unit of Pulsed Electric Field Strength,” Measurement Techniques, vol. 60, n. 11, pp. 1154–1157, Feb. 2018. DOI: 10.1007/s11018-018-1333-5.

A. Sukhov (sukhov@vniiofi.ru)

The State primary standard GET 202-2012 is used for the lightning discharge pulse current unit realization in the range from 1 up to 100 kA. The standard facility includes a 50 kV pulse spark gap generator, a pulse current transformer and output terminals. The sensor transient response rise time can be obtained in the first operation mode (exponential pulse, I_{max} = 1÷8 kA, τ_r/t_p = 0.15/10 μs). The sensor conversion ratio can be obtained in the second operation mode (exponential pulse, I_{max} = 6÷100 kA, τ_r/t_p = 10/40 μs). The expanded uncertainty is 3.0 % (k = 2). VNIIOFI has been working on decreasing the pulse rise time to cover electrostatics.

Publications

Sakharov K.Y. et al. “Metrological Assurance of Measurements of Pulsed Lightning-Strike Currents,” Measurement Techniques, vol. 58, n. 11, pp. 1266–1268, Feb. 2016.

Metrological characteristics of the commercial Josephson voltage standard N4-21 (NNRPA n.a. M.V. FRUNZE and IPM RAS, a_klushin@ipmras.ru)

A compact Josephson voltage standard N4-21 based on high-temperature superconductor (HTS) Josephson junctions with dry nitrogen temperature cooling was calibrated against VNIIM's primary state voltage standard of Russia (PS). The reasons for the verification of the metrological characteristics of the new standard were to link the output voltages of N4-21 to PS. Two types of measurements were performed: an indirect comparison with a traveling voltage standard Fluke 732B (TS) and an onsite direct comparison at VNIIM. The measured relative standard uncertainties between output voltages of N4-21 and the PS are only a few parts in 10^8. The results of the comparisons between the output voltages of the VNIIM's PS, N4-21, and TS demonstrate the suitability of the new voltage standard N4-21 for the highest-level metrology. The implementation of HTS Josephson chip in N4-21 eliminates the uncertainty contributions caused by the nonideal behavior of the electronic dc reference components. It was demonstrated that N4-21 reproduces a dc voltage with an accuracy ensuring the calibration of Zener references at the level of uncertainties comparable with the standards based on niobium arrays of Josephson junctions and cooled at liquid helium temperatures.

Publications

S. K. Khorshev, A. I. Pashkovsky, A. N. Subbotin, N. V. Rogozhkina, M.Yu Levichev, E. E. Pestov, M. A. Galin, A. M. Klushin, "The N4-21 voltage standard based on Josephson junctions of high-temperature superconductors," Meas. Techn., vol. 60, no. 12, pp. 1216–1221, Mar. 2018. DOI: 10.1007/s11018-018-1342-4.

S. K. Khorshev, A. I. Pashkovsky, M. Y. Levichev, E. E. Pestov, M. A. Galin, A. M. Klushin, "Cryocooler operation of a DC voltage standard based on high temperature superconductor Josephson junctions," CPEM Conf. Dig., Jul. 2018, pp. 145–146.

S. K. Khorshev, A. I. Pashkovsky, A. N. Subbotin, N. V. Rogozhkina, Yu. M. Gryaznov, M.Yu Levichev, E. E. Pestov, M. A. Galin, V. Yu. Maksimov, D. A. Zhezlov, A. S. Katkov, A. M. Klushin, "Voltage Standard Based on Dry-Cooled High-Temperature Superconductor Josephson Junctions", IEEE Trans. Instrum. Meas. PP(99):1-8, March 2019. DOI: 10.1109/TIM.2019.2896011.