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Progress report on electrical metrology at CMI between 2019 and 2021

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DC & Quantum Metrology

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A new programmable Josephson Voltage standard was installed.

It is a cryocooled 10 V system with AWG 1104 bias sources and PXI5922 digitizers. The system was manufactured by Supracon. The system was tested on calibration of Zeners, voltmeters, DC and AC voltage functions of calibrators.

For the integration of PJVS into our own automated measurement procedures, the PJVS has got an application programming interface. A new library was developed in CMI and is available at https://gitlab.com/KaeroDot/acsvcontrol-driver
Anyone is welcome to use and co-develop this library.

A new application for calibration of inductive voltage dividers using the PJVS is being developed.

In the framework of EMPIR project QuantumPower, the PJVS system is being integrated into TWM control and calculation software to develop power measurement. The measurement method is based on real time calibration of voltage and current digitizers by the PJVS with the help of specialized multiplexer.

Resistance

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An extension of resistance standards and resistance bridges calibration based directly on CCC was extended up to 100 MΩ. Determination of voltage coefficients of resistance standards was extended from 20 V down to 1.5 V by application of CCC and Hammond transfer standards together with commercial resistance bridges too. Together with results of the key comparison BIPM.EM-K12 between BIPM and CMI, improved CMCs for the resistance range up to 100 MΩ are under review.

Within EMPIR project 18SIB07 GIQS, characterization of graphene based QHR devices at temperature of 4.2 K at low magnet fields from 3 T are ongoing, with observed quantization within few parts in 109.

Impedance

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A reconfigurable digitally assisted and fully digital 4-TP bridge [1] has been adopted for triple series measurement of QHR devices based on graphene. Work has been done within EMPIR project 18SIB07 GIQS and internal projects. With fully digital bridge, 1:1 impedance ratio with 100 ppm out of nominal ratio measurement with agreement within 0.05 ppm was achieved. A direct comparison of capacitance standard 10 nF against quantum Hall standard in AC regime was performed. An agreement of the measurement with AH2700A was better than 0.7 µF/F.

State-of-the-art devices for building primary traceability chains based on precise generators SWG, coaxial multiplexers, calculable standards and digital bridges were distributed to other NMIs. The work is exploited after finish of EMRP project SIB53 AIM QuTE. Within running EMPIR project 17RPT04 VersICaL, a dissemination of know-how related to digital bridges is ongoing and a comprehensive analysis of error sources in electronic fully-digital impedance bridges was performed [2].

New ultralow frequency digital sampling setup for low impedances is being developed in scope of EMPIR project LiBforSecUse. The setup is focused mainly on impedances relevant to lithium battery impedance spectroscopy (EIS), i.e. frequency range is 10 mHz up to 5 kHz and impedance range 0 to 10 Ω. The developed bridge enables measurement of impedance in 4T or 4TP definition with DC bias current and DC bias voltage. Target uncertainties at 1 mΩ impedance are below 100 nΩ. [1]

Special low reactance standard with simulation of DC bias voltage was developed for means of evaluation of parameters of EIS meters in scope of LiBforSecUse EMPIR project [8]. The standard allows generation of DC bias voltage simulating battery cell without affecting simulated impedance. [5]

AC Voltage

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A precision sinewave generator SWG, developed at CMI, was characterized with AC JVS system in cooperation with PTB. The characterization demonstrated, that the generator is a promising alternative for future AC quantum voltmeter comparisons at the level of 0.1 µV/V or even better [3]. A further work in 2020 succeeded in better stability, extension to 100 kHz and lowering temperature coefficient of the generator down to 0.1 µV/V/K at frequency 1 kHz.

Power and Energy

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Precision current transformer from NMIA was purchased for the purpose of measuring electric current and power by means of TWM sampling software. The current transformer enables the measurement of electric currents in the order of 100 mA up to 200 A. High current measurement is necessary for calibration and verification of power analysers and electricity meters that can have current ranges up to 120 A. A voltage current transformer has been developed and manufactured to increase the degree of measurement automation. It is a transformer where it is possible to automatically enter ratios in a

wide range. Used for mains frequency in the voltage range up to 400 V. In 2019 there was also an international comparison *EUR-EM-K5 Power 2019* for AC power. The results of the comparison should be available by the end of 2021.

A unique opensource tool for digital sampling measurement of power and power quality parameters was developed in scope of TracePQM EMPIR project (http://tracepqm.cmi.cz) [7]. The tool is being further developed in scope of EMPIR LiBforSecUse [8] aimed to low impedance measurements and in scope of EMPIR Quantum Power [6] aimed to AC JVS based power measurement. The TWM tool development continues mainly by extending support for more digitizers, more measurement options, such as time multiplexed measurements and more universal interface between sampled data and algorithms.

High voltage and current measurements

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In the field of high voltage measurements CMI has obtained an AC/DC high voltage divider with measuring range up to 100 kV. Accuracy: DC 0.01%; AC 0.5% (50/60 Hz); dividing ratio 1 000:1 DC & AC; input resistance 480 MΩ. Using this divider metrology of DC high voltages was improved.

In the area of instrument transformers ZERA WM3000-I and WM3000-U systems were bought. These systems allow calibration non-conventional current and voltage transformers. Tettex transformer test sets which are at CMI also available do not allow these calibrations.

Participation in comparison:

EURAMET 1187 – Comparison of instrument current transformers up to 10 kA (pilot CMI) completed in 2020

Participation in European projects

14IND08 ElPow - Metrology for the electrical power industry

19NRM05 IT4PQ - Measurement methods and test procedures for assessing accuracy of instrument transformers for power quality measurements **(in progress)**

High Frequency and Fields

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The development of all three national standards maintained by the department has continued. The frequency range of the national standard of RF power was extended up to 50 GHz. Traceable measurements at R400 waveguide and coaxial 2.4 mm connector are now available. The extension of the frequency range of the national standard of electromagnetic field strength up to 40 GHz is being prepared. Set of calibrated horn antennas for the frequency band 18 GHz – 40 GHz was acquired in recent time. Concerning the national standard of reflection and transmission coefficient, traceability for measurements at waveguide R400 (33 GHz – 50 GHz) was established. The low-frequency range of the national standard is now 9 kHz.

Laboratory participated in the following international comparisons:

- BIPM Key Comparison CCEM.RF-K5c.CL, Scattering Coefficients by Broad-Band Methods 100 MHz - 33 GHz - 3.5 mm connector (ongoing)

- CIPM Key Comparison CCEM.RF-K26, Attenuation at 18 GHz, 26.5 GHz and 40 GHz using a step attenuator (ongoing)
- EURAMET Supplementary Comparison EURAMET.EM-S45, Calibration of RF Current Monitoring Probe (ongoing)

The laboratory has been involved in the following European EMPIR projects:

- **EMPIR 18SIB09** TEMMT (2019-2022), http://projects.lne.eu/jrp-temmt/

The role of CMI is cooperation on the measurement of dielectric properties of materials in the frequency band 50 GHz to 1.1 THz and the associated measurement uncertainty using methods in frequency and time domain.

- **EMPIR 20IND03** FutureCom (2021-2024)

The project will start in August 2021. CMI will bring expertise on calibration techniques for signal analysers, including passive inter-modulation testers. CMI will also bring expertise in the characterization of industrial and other non-metrological connectors and characterization of passive devices, including measurement uncertainty evaluation.

Magnetic measurements

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In the field of magnetic measurements CMI developed a system with amorphous AC electromagnet for extending the frequency range of Hall probe calibration up to 1 kHz. RMS values of AC magnetic flux density up to 280 mT (80 Hz), up to 160 mT (405 Hz) and up to 90 mT (930 Hz) can be generated by mean of this electromagnet. CMI is also working on the realization of system for measuring the total losses by Epstein frame up to 1 kHz within the HEFMAG project.

Participation in comparison:

COOMET.EM-S26 - Supplementary Comparison of National Standard Instruments in the Field of Magnetic Flux Density and Magnetic Flux Measurements by Sensing Coils

Participation in European projects

15SIB06 - NanoMag - Nano-scale traceable magnetic field measurements

19ENG06 HEFMAG - Metrology of magnetic losses in electrical steel sheets for high-efficiency energy conversion **(in progress)**

EMC, radio parameters, electrical safety

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TESTING & CALIBRATION, CERTIFICATION

- Testing in Accredited laboratory (EMC, radio parameters, electrical safety)
  According to generic, product (EN), OIML, ETSI and international Standards

  Of broad range of products: legal metrology, multimedia, IT, alarm, automotive, railroad applications, Med, House

- Calibration of Antennas (loop, biconical, log-periodic, hybrid, horn, special)
  According to ANSI, SAE ARP standards
  Frequency range 9 kHz – 18 GHz

- Certification (RED 2014/53/EU) – Notified Body No.1383

INTERNATIONAL ACTIVITIES

- EMRP project IND 60 EMC Industry (2013-2016)
  Improved EMC test methods in industrial environment

- EMPIR project 17NRM02 MeterEMI (2018-2021)
  Electromagnetic Interference on Static Electricity Meters

- Interlaboratory comparisons (EMC)
  - 2017 – Interlaboratory comparison on EN 61000-6-3 with VTÚ s.p.
  - 2018 – Interlaboratory comparison on EN 61000-3-2 with VTÚ s.p.
  - 2019 – Interlaboratory comparison on EN 61000-4-3 with HELLA
  - 2020 - Interlaboratory comparison on ČSN EN 55025 with VTÚ s.p.

- EMC Measurement of railway applications in Europe

- International projects and training of experts
  Project consultation and training for EMC Center Uzbekistan

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