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Progress report on electrical metrology at CMI between 2021 and 2023

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DC & Quantum Metrology

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The programmable Josephson Voltage Standard is being integrated into a power measurement system in the scope of EMPIR project QuantumPower. The PJVS is used to repeatedly calibrate digitizers and the calibrated digitizers measure phantom power of a power source. The advantage is online calibration of the digitizers and released coherency requirements of the whole setup, because the power source can run on slightly different frequency than PJVS. To get the system working a new multiplexer developed by INTI was built and a dedicated software was developed. The software is open source and gives possibility to measure power with the help of PJVS using multiple scenarios. Software is available at: https://github.com/KaeroDot/QPsw . Anyone is welcome to co-develop. The system was presented at CPEM.

Resistance

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Due to extension of validation range of resistance bridges, opreation range of a commercial automated reaistance bridge was extended from 1 GΩ up to 10 GΩ.

Sucesfully finished project EMPIR 18SIB07 GIQS, dealing with realization of both DC and AC resistance impedance standard. Graphene based QHR devices at temperature of 4.2 K at low magnet fields from 3 T were characterized, with quantization within few parts in 109. An interlaboratory comparisons of the quantized Hall resistance was sucesfully performed [11].

Impedance

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Within project EMPIR 18SIB07 GIQS, a reconfigurable digitally assisted and fully digital 4-TP bridge was sucesfully used for AC characterization of graphene-based quantum Hall devices [11]. A direct traceability chain of capacitance unit presented with 10 nF capacitor from graphene-based AC QHR was performed with fully digital bridge at 1.2 kHz. An aditional automation of reversal measurement is in progress.

First interlaboratory comparison of low impedance from 50 µΩ to 100 mΩ in full complex plane for frequencies 0.01Hz to 5 kHz was held in scope of finished LiBforSecUse project [6]. Comparison showed agreement down to order of 100 nΩ [7].

Set of 4TP impedance standards of resistance and capacitance for calibration of RLC meters up to 120 MHz was developed. Characterisation is underway.

AC Voltage

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A new characterization of advanced precision sinewave generator SWG together with a stable output filter, developed at CMI, was performed in cooperation with PTB [12]. For application as an AC transfer standard, the output voltage variations within ±0.05 µV/V for phase shifts between the SWG output and the Josephson waveform up to ±2 ° were achieved. The SWG is adopted as a measurement tool in other laboratories too.

Power and Energy

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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) [10]. The tool was further developed in scope of EMPIR LiBforSecUse [6] aimed to low impedance measurements and in scope of EMPIR Quantum Power [3] 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.

A new multi-range resistive voltage divider covering voltages 50 to 1000 V was developed [8] It enabled further automation of power and PQ sources and analysers calibration.

A synchrophasor measurement system based on commercially available digitizers have been developed. The traceability of the absolute time is provided by a direct sampling of a pulse-per-second time signal and NTP protocol, thus no additional dedicated hardware for time synchronization is needed. Up to it the digitizer can be phase locked to the synchrophasor time base to decrease errors caused by sampling methods. The system is used for calibration of synchrophasor calibrator.

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 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)**

21NRM02 - Digital-IT **(in progress)**

Participation in comparison:

EURAMET.EM-S36 – Calibration of high voltage partial discharge measurement systems **(in progress)**

High Frequency and Fields

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Preparatory works for the extension of frequency range of the national standard of electromagnetic field strength up to 50 GHz started in 2022 and will continue in next years. Preparation for the key comparison CCEM.RF-K5d (S-parameters in 2.4 mm) was ongoing and measurement capabilities for impedance measurements in the frequency range 1 MHz to 3 GHz (APC-7 connector) have been thoroughly analysed.

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 (finished)
- EURAMET Supplementary Comparison EURAMET.EM-S45, Calibration of RF Current Monitoring Probe (finished)

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

- **EMPIR 20IND03** FutureCom (2021-2024) http://www.futurecom.unicas.it/

CMI cooperates on calibration techniques for signal analysers, including passive inter-modulation testers. CMI also cooperates on the characterization of industrial and other non-metrological connectors and characterization of passive devices, including measurement uncertainty evaluation.

- **EPM 21NRM03** MEWS (2022-2025) webpage not yet available

CMI cooperates on (i) traceable methods for measurement of parameters given in ETSI TR 38.827, ETSI TR 38.810 and TS 38.141-2: 5G NR over-the-air, sub-6 GHz and mm-wave MIMO, (ii) measurement protocols to quantify RF exposure levels from 5G base stations, extrapolation methods.

- **EPM 21NRM06** EMC-STD (2022-2025) https://emc-std.cmi.cz/

The role of CMI is the cooperation on (i) development of emission test methods for harsh environments, (ii) characterization of time-domain interference measuring receivers in EMC standards, (iii) methods for calibration of measuring receivers, (iv) characterization of the APD interference detector in emissions compliance assessment.

Magnetic measurements

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In the field of magnetic measurements CMI developed the system for measuring the total losses by Epstein frame up to 1 kHz within the HEFMAG project. Also, a method for traceable measurement of pulse magnetic fields (magnetotherapy) was developed using calibrated PCB search coil and multimeter Keysight 3458A.

Participation in European projects

IND08 – MetMags - Metrology for Advanced Industrial Magnetics

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)**

Participation in comparison:

EURAMET.EM.RF-S46 - Comparison of Magnetic Field Strength Measurements for Frequencies up to 30 MHz **(in progress)**

Digitalization

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The CMI internally start to implement the elements of the digitalization of metrology focusing on crucial aspects such as the implementation of DMP (Data Management Plan), the roadmap of implementation of Digital Calibration Certificates, utilization of Artificial Intelligence in metrology, metrology of sensor network and utilization of digitalization in legal metrology. The CMI is an active partner in working groups dealing with digitalization/digital transformation such as OIML DTG, EURAMET TC-IM working group Metrology for Digital Transformation (WG M4D) and related projects TC-IM 1448 Development of digital calibration certificates, TC-IM 1449 Research data management in European metrology and coordinator of TC-IM 1551 Challenges and opportunities in sensor network metrology.

CMI will participate in project EPM FunSNM (Fundamental principles of sensor network metrology).

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