

## **34<sup>rd</sup> meeting of the CCEM**

**6 – 7 March 2025**

### **Progress report**

### **CEM Electricity and Energy**

The activities of the Electricity and Energy are mainly directed to give fulfilment to the following fundamental points:

a) Establishment, maintenance, conservation, development and dissemination of the national standards of/for the measurement units corresponding to the electrical quantities in DC, LF and EMC. Therefore, the requirements established in the Mutual Recognition Arrangement are fulfilled in their entirety:

- Participation in international key comparisons.
- Declaration of the Calibration and Measurement Capabilities, CMC.
- Implantation of a quality system in the laboratories of the Electricity Division.

b) Execution of research, development and technological innovation projects: National and EMPIR projects.

c) Search and optimisation of methods for the improvement of uncertainty values, the extension of the existing measurement ranges and the beginning of activities in new quantities.

The technical activities can be summarised as follows:

#### **DC Voltage**

Development of fully automatic system for the calibration of high precision calibrators and multimeters.

A system for electrical charge measurements have been finish and CMCs approvd.

Routine calibrations of Zener references and high accuracy voltmeters with the Josephson System.

Routine calibration of DC quantities.

## **DC Resistance**

The laboratory is going to acquire and assemble a CCC (Cryogenic Current Comparator). This system will improve our measurement capabilities. New services of calibration of resistance ratio bridges have been presented in the EURAMET.EM.16.2019 review process. They have been approved in 2022.

The laboratory is going to acquire a new liquid helium free Quantum Hall cryostat System to replace the more than 20 years old cryostat. This will improve research capabilities. The laboratory has acquired a new liquid helium free Quantum Hall cryostat. It has been installed and put into operation.

Calibration of standard resistors and reference groups is ongoing.

## **AC laboratory**

Routine calibration of customers thermal converters, calibrators, digital multimeters and ac/dc difference of resistors and ac dividers have been carried out. The laboratory is currently undergoing automation to optimize the calibration procedures.

A new system for digital sampling low frequencies AC measurement has been developed and CMCs approved.

The lab has acquired systems that reach a current up to 200 A. The automated calibration system RS703 has been modified to reach that current. A new three phase standard has been acquired with current range between 1 mA and 200 A.

The new automated high accuracy current transformer developed by NMIA has been integrated in the CEM sampling systems.

The laboratory is going to arrange a national comparison based on EURAMET.EM-K5, the CEM-K5 comparison. The CEM will be the coordinator and the pilot.

Besides, the CEM Measurement Assurance Program (MAP) continues in order to ensure the traceability of the electrical energy measurement in Spain. This program is based on a set from RADIANT travelling standards.

## **Impedance**

The laboratory continues with the activities leading to the impedance standards maintenance and dissemination and the reference capacitors have been calibrated at BIPM in 2024.

## **Magnetism**

The CEM Magnetic Measurements Laboratory has implemented an active environmental magnetic field system, achieving a residual magnetic field of less than 10 nT. Additionally, the CEM has recently developed procedures for calibrating sensors and generators within the range of 1  $\mu$ T to 100 mT, thereby establishing a new calibration service.

## **Electromagnetic compatibility**

The GTEM cell has been updated with the acquisition of an RF signal generator capable of covering the frequency range from 8 kHz to 6 GHz. Additionally, the D-band (0.69 GHz to 3.2 GHz) of the power amplifier has been expanded to 60W, and the power amplifier has been extended to the E-band (2.5 GHz to 6 GHz) by adding a new module for this band.

Electric field at industrial frequencies standard has been improved, along with a new uncertainty calculation considering the corrections to the field due to the probe position inside the parallel face capacitor.

## **New laboratories**

### **Electrical Vehicle Charging Stations**

CEM has been working in the development and testing of a new laboratory for the metering characterization of AC and DC electrical vehicle charging stations [8]. Different operating conditions both on the grid side and EV load has been implemented. Additionally, CEM has initiated procedures to further develop the test bench to establish traceability.

## **Frequency**

CEM has been working in the development of an optical clock based on  $\text{Ca}^+$  ion trap. All the necessary equipment for the system has been acquired, not only the main components, such as the ion trap, the frequency comb or the laser system, but also auxiliary instruments. At the same time, the installation and integration of all of them has been carried out during this period and is in its final stages, with the expectation of being able

to start trapping ions in the short term. Finally, new staff has started working at full time in this researching line.

### **Comparisons**

CEM will participate in the comparison of capacitance RMO key comparison EURAMET.EM-K4 and measurement will be carried out at the end of 2025.

In the field of AC-DC Voltage Transfer, CEM will participate in the EURAMET.EM-K6c for AC-DC Voltage Transfer Standards in the frequency range of 1 MHz to 100 MHz, the EURAMET.EM-K6a for Medium Voltage Transfer Standards, and the EURAMET.EM-K9 for High Voltage Transfer Standards, all expected for June 2025.

### **Participation in European projects (2023-2024)**

20FUN03 COMET, Two dimensional lattices of covalent- and metal-organic frameworks for the quantum Hall resistance standard. Coordinated by CEM was successfully completed during 2024.

21SCP02 TRaMM: Traceability Routes for Magnetic Measurements. This project was successfully completed in February 2024, identifying the magnetic metrology needs and developing strategic development plans.

The MetroMag project, aimed at establishing a European infrastructure for low magnetic field metrology, has been selected for funding under the 2024 Research Potential Call and will begin in July 2025. CEM is the leader of a work package.

The 23RPT01 WAC project, focused on developing a wideband quantum-based voltmeter operating at frequencies up to 100 kHz, started in June 2024, with CEM as the leader of the impact work package.

The MET4EVCS, Metrology for electric vehicle charging systems has started in July 2024. The 23IND06 Met4EVCS project aims to develop operational reference test benches to enable accurate characterisation of energy metering and transfer efficiency for

AC and DC EVCS under real operating conditions. CEM is the leader of the WP2 work package.

MADQUANTUM-CM: This project focuses on the development of a quantum communications network in the Comunidad de Madrid. For this purpose, several nodes are established, among which is CEM. In addition, CEM plays an important role in the fourth line of the project, being responsible for developing the hardware for quantum processing. To this end, an ultra-accurate frequency standard is developed at its facilities to serve as a reference for the rest of the nodes.

### Publications

[1] “*Bilateral comparison of 1  $\Omega$  and 10 k $\Omega$  standards (ongoing BIPM key comparisons BIPM.EM-K13) between the CEM (Spain) and the BIPM Final Report*”, B. Rolland , P. Gournay, M. Stock, L. Matías, A. Hortelano, F. Raso, J. Díaz de Aguilar. Metrologia, Vol. 60 (1), 2023. DOI 10.1088/0026-1394/60/1A/01008

[2] “*Magnetic measurements traceability at CEM*”, S. Moltó, Y. A. Sanmamed, J. Díaz de Aguilar, M. Coisson, V. Basso, R. Walsh, O. Larmour, O. Power, Oliver. Measurement: Sensors, 2024. DOI: 101442. 10.1016/j.measen.2024.101442.

[3] “*Magnetic Measurement System and Environmental Magnetic Field Compensation at CEM*“, S. M. González, Y. Á. Sanmamed and J. D. d. A. Rois. IEEE Transactions on Magnetics, vol. 60, no. 11, pp. 1-4, Nov. 2024. D.O.I.: 10.1109/TMAG.2024.3417485.

[4] “*Traceability routes for magnetic measurements: filling the gap between the magnetism community and the European NMIs offering*“, M. Coisson, J. Diaz De Aguilar Rois, Y. Alvarez Sanmamed, S. Molto González, O. Power, R. Walsh, O. Larmour, Acta Imeko, 13 (4), 1-6, 2024. DOI:10.21014/actaimeko.v13i4.1762

[5] “*High Accuracy Calibration Methods for the Input Stage of an Ultrastable Low-noise Current Amplifier without a Cryogenic Current Comparator*”, F. Raso, D. Peral, L. Matías, E. Campillo, A. Hortelano, J. Díaz de Aguilar, and M. Götz, Conference on Precision Electromagnetic Measurements CPEM 2024. DOI: 979-8-3503-6104-9/24/\$31.00.

[6] “*Magnetic Measurements Traceability at CEM*”, S. Moltó González , Y. Álvarez Sanmamed, J. Diaz de Aguilar Rois, M. Coisson , V. Basso, R. Walsh , O. Larmour , O. Power. IMEKO WORLD CONGRESS 2024, 2024.

[7] “*CEM’s  $^{40}\text{Ca}^+$  optical clock for the second quantum revolution*”, A. Palos, D. de Mercado, I. Caballero, Y. Álvarez, D. Peral, J. Díaz de Aguilar, COLD ATOM WORKSHOP BARCELONA 2024.

[8] “*Metrology for electric vehicle charging stations*”, J. Diaz de Aguilar, M. Luisa Romero, L. Matías, D. Peral, Y. Álvarez, M. Cervantes, R. Morales, A. Pueyo.