INTI

Instituto Nacional de Tecnología Industrial, INTI, ARGENTINA

Report on Research and Development Activities in Electricity and Magnetism 2016-2018

CCEM Meeting, March 2019

During August 2017, a peer review of electricity measurement capabilities was successfully carried on by an expert from VSL. The aim of the peer review was to determine whether the INTI quality system sufficiently supports the CMCs of INTI in the DC and LF electrical area published in the BIPM KCDB as part of the CIPMMRA. The review was based on the criteria of the ISO 17025:2005 standard.
The scope of the review concerns all DC and Low Frequency calibration activities of INTI that have CMCs in the BIPM KCDB.
The final conclusion of the peer review was that the INTI Fisica y Metrologia department, Technical unit for Electricity, had implemented a QMS that supports their CMCs in the area of DC and LF electrical quantities as presently published in the BIPM KCDB.

1. Quantum Standards

1.1. Transport Phenomena of Quantum Hall Effect Systems

(Contact: Mariano Real, mreal@inti.gob.ar and Alejandra Tonina, atonina@inti.gob.ar)

This project is aimed to achieve experimental developments of transport and thermal transport properties of the quantum Hall effect (QHE), to have greater comprehension and manipulation of edge states in these systems with applications in metrology.

The Quantum Standard Laboratory has adapted and extended its instruments and capabilities: two lock-in amplifiers have been purchased (from a grant, PICT 2049), a variable temperature insert have been set up which includes a new external temperature controller and the previous He3 insert have been modified to be able to obtain and keep 300 mK as specified originally.

The theoretical support for these developments is carried out in the quantum transport group of ICAS-UNSAM (International Center for Advanced Studies placed at University of San Martín).
Following a proposal by Barlas and Yang [1] we aim to study the behaviour of the bulk using Corbino structures; by means of a central resistive heater a temperature radial gradient on the sample is obtained. The thermal response is assumed to be instantaneous given the characteristic time constants of the system, so it is measured locking to twice of the heater excitation frequency. Measurements on this geometry have been carried out in the past with different techniques and larger temperatures [2], also in different geometries [3] and deviations from homogeneity have been found [4].

Initial development of samples were carried out at INTI/CNEA and tested in a cryofree system (IFLISyB, Dr. Grigera´s Lab) and then at INTI, these initial measurements were published in the Licenciatura thesis of Jimena Siepe (now at Dr. Molenkamp´s lab in Würzburg) under Dr. Tonina´s direction.

A second round of mesurements on improved samples (GaAs/AlGaAs provided by Dr. W. Dietsche) were made at

INTI. In this case some were processed at INTI while others at MPI. Another set of samples have been measured at ETH Zürich. These measurements showed several interesting thermal-transport properties and now are being modelled (ICAS-INTI). A publication of all this results is under development.

[1] Y. Barlas and K. Yang, Thermopower of quantum Hall states in Corbino geometry as a measure of quasiparticle entropy, Phys. Rev. B 85, 195107 (2012)
[2] S. Kobayakawa, A. Endo, and Y. Iye, Diffusion Thermopower of Quantum Hall States Measured in Corbino Geometry, J. Phys. Soc. Jpn. 82, 053702 (2013).
[3] WE Chickering, JP Eisenstein, LN Pfeiffer, KW West, Thermoelectric response of fractional quantized Hall and reentrant insulating states in the Landau level Phys. Rev. B 87, 075302 (2013).
[4] N. d'Ambrumenil and R. H. Morf, Thermopower in the Quantum Hall Regime Phys. Rev. Lett. 111, 136805 (2013)

2. DC standards measurement improvement and capabilities extension

2.1. Set-up and study of a new 300 A DC bridge and range extender

A new DC bridge with a range extender and current sources was acquired; this system extends the range of calibration currents that can be achieved by our resistance laboratory. The system was set-up and studied to ensure that its specifications were met. A new procedure for calibration of high current resistors up to 300 A have been made and presented during a peer review. The latter suggested several tests to be performed, which were made and concluded that the system is working as expected.
Given these improvements, new CMCs will be presented, extending the range of DC currents to 300 A and also improving the ones we had, especially for resistances lower than 0.1 Ω.
Thanks to this system some new studies will be carried out, particularly we will be able to measure temperature and power coefficients for our low resistance (high current) standards. For this, an undergraduate student will be included to our laboratory, for him to produce such measurements and also include temperature sensors on our laboratory standard shunts [1,2].

[1] Rietveld, Gert, et al. "Low-ohmic resistance comparison: Measurement capabilities and resistor traveling behavior." IEEE Transactions on Instrumentation and Measurement 62.6 (2013): 1723-1728.

[2] Kraft, Marlin. "Measurement Techniques of Low-Value High-Current Single-Range Current Shunts from 15 Amps to 3000 Amps." NCSLI Measure 2.1 (2007): 44-49.

2.2. Waveform metrology based on spectrally pure Josephson voltage. 15SIB04 QuADCEMPIR-EURAMET 2016

(contact Ricardo Iuzzolino, ricardo.iuzzolino@inti.gob.ar)

This Joint Research Project (JRP) will develop measurement systems centered on true AC-voltage quantum devices which will both operate at the highest level of accuracy and be simple enough for exploitation outside the national metrology institutes. The term 'true quantum devices' refers to the recently achieved breakthrough which provided spectrally pure quantized Josephson AC-voltages exceeding for the first time the usability threshold of 1 V RMS. In this JRP, innovative use of Josephson junctions is proposed for measurements of arbitrary signals in terms of fundamental constants referenced to the volt in the new SI. The need for this development is clearly driven by development in the application fields: Sensing and measurement are increasingly dependent on fast analogue-to-digital conversion. Recent R&D in precision integrated circuits and measurement equipment has brought about a step change in the sampling rates and accuracies available. Whereas direct traceability of DC electrical metrology to quantum standards is well established, emerging measurement applications in high end equipment are placing new demands on the traceability for dynamic quantities, which cannot be satisfied by the existing approaches. Fluke e.g. has written "One of the barriers to reducing the uncertainty of these multifunction calibrators for AC voltage is the magnitude of uncertainty inherited in the traceability chain."

The overall objective of this JRP is to provide for all end-users direct, efficient, and highly accurate traceability of AC-voltages to the SI volt for dynamic measurements in the most relevant range of DC to 1 MHz, up to levels of 1 kV.

INTI is participating as founded partner in Working Package no.1. The aim of this work package is to design and build a quantum voltage digitizer. Delta sigma electronics, a pulse generation system and a feedback loop will be developed.

The components developed in WP1, together with the quantum-accurate system developed in WP2 will form a quantum voltage digitizer, which will be tested and characterized in WP1. Together with the voltage dividers (WP3) the system will be used in WP4 to develop the methodology for characterization of industrial devices. It will also be used to calibrate some industrial instruments in WP4.

The quantum voltage digitizer will operate over DC to 1 MHz frequency range with a target uncertainty of 10 nV/V level for frequencies up to 5 kHz and better than 10 μV/V for frequencies up to 1 MHz. The sampling rate will be 100 MHz and the input will be +/-1 V maximum. The spectral purity (SINAD) will be better than 110 dB. At lower frequencies distortion levels of better than -140 dB are expected.

The practical realization will use specially designed circuitry rather than off-the-shelve hardware. Further expertise will be drawn from international experts (APPLICOS, INTI and Signal Conversion) to result in a robust, flexible and optimized design providing a state-of-the-art system. Building on the EMRP project, the frequency range will be extended by a factor of ten, the uncertainty lowered by a factor of ten and the sampling rate increased by a factor of 10. This quantum voltage digitizer will be key in Europe's future provision of quantum-accurate AC voltage metrology to NMIs and industrial users.

Advances in the implementation of the quantum voltage digitizer were performed: i) The Sigma-Delta electronics has been designedand implemented which consist of a fourth order loop filter, ii) FPGA firmware to read the ADC data, send pulses to the pulse driven Josephson array trough optoelectronic and close the loop was done.

A joint publication was presented at the CPEM 2018 about WP1 Sigma-delta electronic task:
R. Iuzzolino et al., "Design and Simulation of a High-Order Sigma-Delta Continuous-Time Modulator," 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018), Paris, 2018, pp. 1-2.
doi: 10.1109/CPEM.2018.8501196
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8501196&isnumber=8500784

2.3. Infrastructure for direct traceability to the unit volt of novel digital sampling algorithms with quantum voltage standards. Joint Project INTI-PTB under bilateral Argentine-Germany cooperation program MINCyT- BMBF.

(contact Ricardo Iuzzolino, ricardo.iuzzolino@inti.gob.ar)

The main goal of this Project is to join the volt unit directly to sampling algorithms at INTI. To accomplish the objective INTI is upgrading its Josephson system to a programmable system in cooperation with PTB. And, INTI is improving its sampling system based on sigma-delta ADC techniques to measure ac signal in the amplitude range up to 1 V with frequency up to 100 kHz.
The MINCyT and its counterpart, BMBF, are given financial support for scientist exchange from both institutions.
This Project has finished with a joint presentation at the CPEM 2018:
R. Iuzzolino, M. E. Bierzychudek, L. Palafox, R. Behr and A. Tedesco, "On the Development of an AC-Quantum Voltmeter," 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018), Paris, 2018, pp. 1-2.
doi: 10.1109/CPEM.2018.8500894
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8500894&isnumber=8500784.
So far, INTI has builta six-channel programmable bias source for the Josephson 1 V array, the firmware to control it, the cryoprobe and the digitizer. All these parts were joint together in orderto construct a quantum voltmeter.

3. Power and Energy

3.1. Phasor measurement system for the development of smart grids

(Contact Lucas Di Lillo, ldili@inti.gob.ar)

The present work is a joint development between the INTI (National Institute of Industrial Technology), the Center for Computational Simulation of CONICET (CSC), Institute of Technological Research for Networks and Electrical Equipment (IITREE) of the Faculty of Engineering of National University of La Plata and COMPUTEC SRL with the aim of design, development and construction of a phasor measurement unit (PMU) that fulfils the requirements of the IEEE Standard C37.118.1-2011

This project involves I&D activities in various disciplines: electrical metrology, signal analysis, embedded software, electronic design, power system analysis and electromagnetic compatibility. The experience of the different groups is complemented to cover all the necessary expertise. The project consist of three working package

WP1. Development of a commercial PMU that fulfils the requirements of the IEEE standard C37.118.1-2011

The aim of this subproject is base on testing and selection of the appropriate spectral estimation algorithms for synchrophasor estimation, development of current and voltage transducers to adapt the input signals to the levels required for the internal electronics, development of the PMU communication module and the implementation of PMU electronics and embedded software.

WP 2. Development of PMU test platform

The aim of this subproject is the development of a reference system for the calibration of PMUs and the implementation of the Electromagnetic Compatibility and Electrical Safety Tests.

WP3. Development of software tools for the processing and analysis of synchrophasors.

The aim of this subproject is the development and implementation of synchrophasor processing and analysis software as well as the optimization of the sensor network.

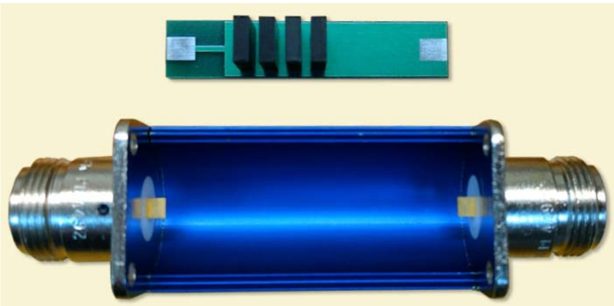
Concerning the activities of WP 1 and WP 2, an algorithm for the calculation of the synchrophasors that fulfils the requirements IEEE Std. C37.118.1 was designed. Also, a synchronous generation and sampling system was designed to compare the synchrophasors measured by the PMU under test with the reference synchrophasors generated by the reference system. The reference synchrophasorsare estimated by polynomial approximations that are solved by the least square method. For the validation of these approximations a comparison was made between the synchrophasors obtained by the synchrophasor laboratory the METAS for stationary test and the frequency ramp, obtaining satisfactory results. One of the activities of WP 3 is and the implementation of synchrophasor processing and analysis software. The objective is focused on the processing of data collected from a number of PMUs that may be installed on the network. To achieve this goal, an online processing module is being worked out in which phasor diagrams and trend diagrams are displayed in graphic form, allowing a real-time view of the behavior of the power system. On the other side, a second offline module which is capable of processing the data and it will can show and analyze events such as decomposition into sequence components and analysis of system oscillation modes. The following figure shows the first prototype

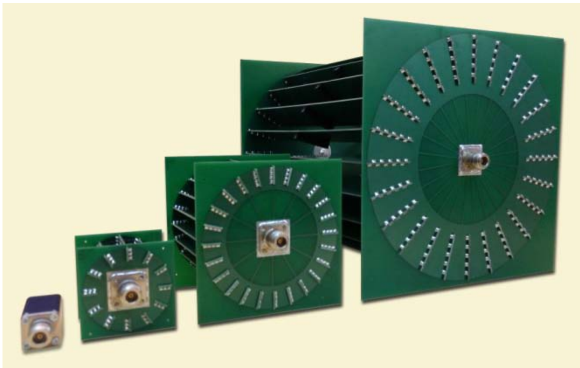
3.2. High frequency wattmeter

(Contact Lucas Di Lillo, ldili@inti.gob.ar)

The Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO), in Brazil, the Instituto Nacional de Tecnología Industrial (INTI), in Argentina, and the Administración Nacional de Usinas e Transmisiones Eléctricas (UTE), in Uruguay, are jointly developing a reference system for measuring electric power up to 100 kHz. The objective is the construction of three similar measuring systems, one for each institute.
This project will contribute to provide calibration services in measuring ranges still not covered by the three institutes. The project will also contribute to improve the traceability not only of electric power but also of related quantities like ac-dc transfer, voltage ratio, phase angle, ac voltage and ac current. The project is coordinated by INMETRO, who is responsible for the purchase and transportation of the components and parts needed to the construction of the modules, and for the transportation of the modules needed to the assembly of the measuring systems, in each partner country.
INMETRO is also responsible for the development of the wideband power and transconductance amplifiers and of new digital sampling algorithms. INTI is responsible for the development of the arbitrary waveform function generator, the dual-channel digitizer and the current shunts (and their calibration). UTE is responsible for the development of the resistive voltage dividers (and their calibration).

The following figures show the first set of shunts made at INTI





Advances in the calibration in module and phase has been done and the system is almost complete A joint publication was presented at the CPEM 2018:

L. Di Lillo, E. Yasuda, L. Dominguez Pose, G. A. Kyriazis, " Construction of new shunts for wideband sampling wattmeter" 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018), Paris, 2018, pp. 1-2.
DOI: 10.1109/CPEM.2018.8501201
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8501201

The project activities include the design, layout and documentation of the printed circuit boards of the modules, the design and documentation of the electronic packaging of the modules, the calibration of resistive voltage dividers and current shunts, the design and documentation of the software and firmware, and the measuring system integration, testing and documentation.

Advances in the dual-channel digitizer has been done, the system is almost complete and it will be calibrated against a programmable Josephson system at 1 V rms. A joint publication was presented at the CPEM 2018:
R. Iuzzolino, A. Tedesco and G. Kyriazis, "A Broadband Two-Channel Sigma-Delta Digitizer for Power Measurement - Design Concepts," 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018), Paris, 2018, pp. 1-2.
doi: 10.1109/CPEM.2018.8501034
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8501034&isnumber=8500784

The project is supported in part by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), in Brazil.

4. High Voltage

4.1. 300 kV Impulse reference voltage divider

(Contact José Luis Casais, jcasais@inti.gob.ar)

An impulse reference voltage divider up to 300 kV was designed and built. It consisit of of 20 modules of 15 kV each of them formed by high voltage capacitors and resistors. It is in the characterization and calibration stage to obtain its scale factor. This divider will be used as a reference for direct calibration of pulse splitters up to 1.2 MV

5. RF Metrology

A peer review of RF measurement capabilities was successfully carried on by an expert from PTB. The Quality Management System has been reviewed and approved by the SIM QSTF. This peer review, in addition with the already finished key comparison named SIM.EM.RF-K5b.CL are the supporting evidence of competence of the laboratory to attain declaration of CMCs in the CIPM MRA database. This process of declaration is still in progress.
Capabilities proposed to be included in the Appendix C of MRA are:
- S-parameter measurements with Type-N and 3.5 mm of one and two-port devices.
- Calibration Factor and power linearity measurements on thermistor and thermoelectric power sensors with type-N connector up to 18 GHz.
- Absolute RF power measurements and RF power generation up to 18 GHz on coaxial lines with type-N connector.
- Attenuation Measurement on type-N connector at 1 GHz.

- Output reflection coefficient measurements from RF Generators up to 1 GHz.

5.1. Scattering parameters

(Contact Guillermo Monasterios, guillem@inti.gob.ar)

Vector Network Analyzers (VNA) are used as working standards at INTI to measure scattering parameters (complex values) of systems that use Type-N, 3.5 mm and 2.92 mm connectors, covering a frequency range up to 40 GHz.
The uncertainty evaluation has been improved and now uncertainties from the cal kit standards are propagated through the calibration algorithm taking into account full covariance matrices. This method is based on ripple method for primary standards and rigorous propagation method for the DUT measurement as was presented at CPEM 2018 in Paris. (Mixed Uncertainty Propagation Method in S-parameter Measurements).

5.2. Power Standard

(Contact Alejandro Henze, ahenze@inti.gob.ar)

Full-automatic thermistor mount or thermoelectric power sensors calibration for type-N connector between 10 MHz and 18 GHz is provided with basic accuracies between 0.5 % and 2 %.Thermistor mount or thermoelectric 3.5mm power sensors calibration service up to 26.5 GHz is in its final stage to be operational.
Low frequency power calibration system for ranges between 1 MHz and 100 MHz is being developed with traceability to DC calorimetric power standard.

6. Electromagnetic Fields

6.1. Performance of broadband hybrid antennas for EMC measurements

(Contact Luciano Blas, emc@inti.gob.ar)

This work studies the critical metrological characteristics of the hybrid broadband antennas, like the used BiConiLog antenna, when they are used as reception antennas in the 10m measurements of electromagnetic field strength, polarized horizontally. This study's finality is to evaluate the hybrid broadband antennas contribution in the measurement uncertainty budget.