Measurement Standards Laboratory of New Zealand

Report on Electromagnetic Metrology Activities at MSL, New Zealand Prepared for the 31st Meeting of the CCEM, 28 and 29 March 2019

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Introduction

This report covers activities of the Electrical Standards and RF Standards sections of the Measurement Standards Laboratory of New Zealand (MSL) carried out since the 30th meeting of the CCEM (2017).

Staff

Manager: Mr Cliff Hastings

(i) DC/LF

- Dr Laurie Christian - Josephson voltage standards, dc high resistance, dc high current
- Mr Keith Jones – impedance, current transformers, on-site metering accuracy
- Dr Murray Early – AC voltage and current, DC voltage, quantum Hall/CCC
- Dr Vladimir Bubanja – SET modelling and AC/DC voltage
- Dr Tim Lawson - quantum Hall/CCC, dc high resistance
- Mr Tom Stewart - mains energy, impedance
- Mr Bruce McLennan – mains energy and dc resistance
- Mr Cheng Yang: digital instruments and time standards
- Mr Adam Knight: mains energy, high DC current and low resistance

(ii) RF

- Dr Blair Hall: RF Standards, MSL Quality Manager

MSL Management

MSL Director: Dr Fleur Francois

Chief Metrologist: Ms Eleanor Howick. The Chief Metrologist for MSL has legal standing in the NZ Measurement Standards Act as a verifying authority for measurement standards.

Quality Manager: Dr Blair Hall

Manager Electricity, Time and Frequency: Mr Cliff Hastings
Manager Temperature and Light: Ms Michele Thompson
Manager Mass and Length: Mr Kevin Gudmunsson

Following an external review, significant additional funding was awarded to MSL in the 2018 NZ Government budget to be spread over five years, addressing both operating and capital

expenditure concerns. This has come at a critical time to address resilience issues for MSL regarding aging equipment and staff! As a result, two new staff were appointed in 2018 to technical roles. Cheng Yang has previous experience in an aviation laboratory and is developing procedures to extend our digital instrument calibration services and is also working in the Time Standards section. Adam Knight has previous experience in an accredited laboratory and will be involved in calibrations in support of the electricity industry.

SI Redefinition

To promote the understanding of the upcoming redefinition of the SI a number of presentations have been given to a range of different audiences particularly in New Zealand. These include:

[1] M D Early, *The Last SI Revolution?*, Plenary presentation to the NZ Institute of Physics Conference, Dunedin, New Zealand, July 2017.

[2] M D Early and I Budovsky, *Electrical Metrology and the Revised SI*, Oral presentation to the Metrology Society of Australasia Conference, Brisbane, Australia, September 2017.

[3] M D Early, μ_0 *and the SI*, Oral presentation to the APMP TCEM Workshop, New Delhi, India, November 2017.

[4] M. D. Early, *Redefinition of the SI for the 21st Century*, Oral presentation at the MSL World Metrology Day symposium, Lower Hutt, New Zealand, May 2018.

[5] M. D. Early, *Redefinition of the SI and Atomic Clocks*, Oral presentation at the Annual Meeting of the NZ Horological Institute, Wellington, New Zealand, May 2018.

[6] M D Early, *Conceptual Consequences of the SI*, Poster presentation at the Conference on Precision Electromagnetic Measurements (CPEM), CPEM Digest, July 2018, Paris.

[7] M D Early, μ_0, Oral presentation to the IEEE I&M NZ Chapter Workshop, Palmerston North, New Zealand, September 2018.

[8] F. Masouleh and M. D. Early, *The 2019 Redefinition of the International System of Units*, Oral presentation to the IEEE I&M NZ Chapter Workshop, Palmerston North, New Zealand, September 2018.

[9] F. Masouleh and M. D. Early, *Understanding the Revised SI*, abstract submitted to the NZ Institute of Physics Conference, Christchurch, New Zealand, April 2019

Investigations into the historical development of the Giorgi System reported in some of these presentations [3-7] have highlighted the peculiarity of naming μ_0 as the permeability of free space when it is simply a conversion factor going from CGS to SI units. The alternative name ‘magnetic constant’ is to be preferred.

From March to May 2019 MSL staff are participating in five workshops in different NZ cities to promote the revision to the SI to a wider audience.

Electrical Standards Laboratories

The Electrical Standards section has been working in rather trying conditions since the positive result for asbestos in the building housing the MSL Electrical, Temperature, and Time Standards laboratories in 2016. The initial plastic lining of the laboratory ceilings, allowing us to continue operations, was considered to require improvement. Since November 2018 the laboratories have been emptied of all equipment, the ceilings have been removed and all dust extracted or sealed, and a new plastic lining has been installed. We are now at the stage of moving most of the equipment back to the laboratories to continue operations.

Work began on a new building to house the Temperature and Electrical sections of MSL in February and this is expected to be completed late 2019. There will be another significant downtime during which the laboratory equipment is shifted into the new building and commissioned. Plans are also being prepared to create a new laboratory space in an existing building to house RF standards and Time Standards. This renovation work should be completed mid-2019

This has been a really difficult time to maintain our metrology work and has unfortunately led to withdrawal from several comparisons, deferment of calibration services, and a growing back-log of development and equipment commissioning work.

A positive consequence of the concern around moving and re-establishing old equipment in the new building is that additional capital funding has been allocated for the Temperature and Electrical sections of MSL. Electrical Standards has purchased new low resistance/high current measurement system to better support the magnet manufacturing industry in NZ, a wideband harmonic power standard from NMI Australia and a new CT calibration system to support the NZ power industry, as well as new oil and air baths. In some cases, these investments are replacing 40-year-old systems.

17025 Accreditation and Peer Review

A full assessment of the capabilities of the Electrical Standards Team was carried out in April 2018 involving peer technical assessment by Dr Wey Chua (NMC) and Mr Lucas di Lillo (INTI) working with two assessors from the New Zealand accreditation body, IANZ. Corrective actions related to this assessment have been cleared. In March 2019 IANZ carried out an annual surveillance assessment of all MSL, including the Electrical Standards section, according to the recently revised version of ISO 17025:2018. There were no corrective action findings from this assessment.

It has been decided to defer the reassessment of the RF capabilities until adequate laboratory facilities are available. As a result, the CMC for RF power has been temporarily suspended (‘greyed out’).

International/CPEM

Keith Jones continues to assist the Myanmar Government with the establishment of their national metrology system. His work is funded by the German Government as part of their international aid to the Asia-Pacific Region.

Murray Early completed his role as chair of the APMP Technical Committee for Electricity and Magnetism at the APMP General Assembly in Singapore, November 2018. He continues to support the new chair Dr Hyung-kew Lee of KRISS as TCEM vice-chair until November 2019.

CPEM 2022 will be held in Wellington New Zealand on the first week of May 2022 (Sunday 1st May to Friday 6th May). The conference will be jointly hosted by MSL and NMI Australia. A 'Request for Proposals' for a Professional Conference Organiser (PCO) has just been published on the NZ Government procurement website, and a contract to secure the Michael Fowler Centre (https://www.venueswellington.com/venues/michael-fowler-centre/) as the venue is near completion.

Kibble Balance

The MSL Kibble balance based on a twin pressure balance concept is now under construction. Sadly, Dr Chris Sutton, who came up with this novel concept and is the primary architect of the MSL Kibble balance, passed away in December 2018. Dr Annette Koo is now managing a larger group of people to maintain progress on this project. Many of the Electrical Standards section are contributing to this effort. The 2 V PJVS system, based on a chip kindly provided by NIST, has been transferred to the laboratory containing the Kibble balance, in part because of the building issues facing the Electrical Standards section.

SET Devices

We consider the transport properties of a SINIS single electron transistor. The expression for the critical supercurrent is derived considering the interplay of a dissipative impedance of the gate electrode and a quantum size effects of the normal-metal island. We show that a weak magnetic field causes the mixing of transport levels of electron pairs on the island and in that way suppresses the critical supercurrent. When the device is voltage biased, pumping of single electrons can be achieved by a periodic modulation of the gate voltage. We derive the analytic expressions for the error rates and show that they are suppressed by the applied magnetic field.

This work is in part supported by the Dodd-Walls Centre for Photonic and Quantum Technologies, which is one of ten New Zealand Centres of Research Excellence.

[10] V. Bubanja, "Effect of quantum fluctuations on the critical supercurrent through a mesoscopic normal-metal island", Physical Review B 97, 224516 (2018).

We investigate the effects of uniaxial compressive and point tensile strains on graphene nanoribbons of various shapes and under variety of boundary conditions. We observe the changes in the geometric, electronic and magnetic properties by using the spin polarised calculations within the framework of density functional theory [11].

For this work we employ the supercomputing facilities of the New Zealand eScience Infrastructure (NeSI).

[11] S. Kaur, H. Sharma, V. K. Jindal, V. Bubanja and I. Mudahar, "Graphene nanoribbons under axial compressive and point tensile stresses", Physica E 111, 1 (2019).

Mains Frequency Transformer Calibration

The NZ electricity industry remains committed to investigating secondary injection techniques for transformers as a replacement for traditional primary injection methods when certifying metering installations on the national grid. The major benefit will be ease of complying with safety regulations when accessing the metering sites. The challenge is to achieve expanded uncertainties of 0.1 % or less under field conditions.

DC Voltage

Further development work using the MSL Reference Step Method concept has been carried out to build up our dc current scale, reported at CPEM 2018 [12]. This work is being carried out in support of magnet manufacturing industries in NZ.

[12] L A Christian, *Accurate High Direct Current Measurements for Industry*, Poster presentation at the Conference on Precision Electromagnetic Measurements (CPEM), CPEM Digest, July 2018, Paris.

RF and Microwave

- In March 2018, MSL decided to maintain current RF capability but not to invest in planned maintenance and development activities requiring capital. The decision will be reviewed in September 2019.

- In a collaboration with Thomas Reichel (formerly of Rohde & Schwartz), a short analysis of the Ripple Method was carried out with the aim of clarifying the influence factors that should be accounted for in an uncertainty analysis of ripple measurements [13]. This work derived measurement models for residual source match and residual directivity measurements. These models lead to different expressions for the measurement uncertainty than the expressions presented in the latest EURAMET calibration guide for VNAs (cg-12 v3). We have contacted the authors of that guide and submitted our report for consideration when the guide is next reviewed.

  [13] B. D. Hall and T. Reichel, *"An uncertainty analysis of the ripple method"*, Callaghan Innovation Report 593, June 2018.

- Work on the propagation of errors in the TRL family of calibrations was presented as a poster at CPEM 2018 [14]. In support of that work, a report was prepared that presents in much greater detail the principle of the method and its application as an algorithm [15].

  [14] B. D. Hall, D. Allal, A. Litwin and F. Ziadé, *"Evaluating the uncertainty of self-calibrating VNA procedures"*, Symposium Digest, CPEM 2018, Paris, France.

  [15] B. D. Hall, *"Evaluating measurement uncertainty when calibration equations assume ideal standards"*, Callaghan Innovation Report 592, June 2018.

- MSL software for data processing with automatic propagation of uncertainty has been released in an open-source form. This pure Python version of the GUM Tree Calculator is available from a public github repository (https://github.com/MSLNZ/GTC).

Status of Comparisons

1/ APMP.EM-K2: High resistance at 10 MΩ and 1 GΩ, draft B (support group).

2/ APMP.EM.RF-S6.CL: Bilateral comparison of scattering parameters for Type-N, 50 ohms connectors: technical protocol approved but NMIJ has decided to suspend participation. MSL may consider supporting a similar comparison at a later date.

3/ APMP.EM.RF.K8.CL: RF power in 50-Ohm coaxial lines, report submitted, waiting on draft A.

4/ APMP.EM-K5.1: AC power at 50 Hz, draft B.

5/ APMP.EM-K12: AC-DC current, withdrawn owing to building issues. However, as part of the support group we have had a summer student checking the preliminary calculations with some useful findings.

6/ APMP.EM-S12: Voltage, Current and Resistance Meters, participated in 2016 but withdrew owing to building issues.