KRISS Korea Research Institute of Standards and Science

Progress Report of KRISS Electromagnetic Metrology

(31th meeting of the CCEM, March 2019)

This report gives a brief summary of the main activities in the area of Electricity/Magnetism and RF at KRISS since the last CCEM meeting (March 2017). Progress in blue

1. Electrical Quantum Standards

1.1 Kibble Balance

Contact: Dr. Kwang-Cheol Lee (kclee@kriss.re.kr)

The KRISS Kibble balance uses a commercial weighing cell of 5 kg capacity which is moved using a counterbalanced mechanism incorporating a piston/cylinder guide and flexure guide. The mass pan and mass exchanger are placed below the magnet.

The magnet has been constructed and displays a field uniformity of 3.9 x 10^{-4} over a 20 mm range. The system has been mounted in its vacuum chamber and is working in vacuum. They have tested the coil drive mechanism which gives a constant velocity of 2 mm/s with a type A relative standard uncertainty of approximately 7 x 10^{-3} using a linear motor. They have developed a control servo for the motor using both velocity feedback and feed-forward to improve the performance of the system. Their coil support structure has been fabricated in PEEK and has a high resonant frequency. The coil former is made of Zerodur and is provided with six retroreflectors and three alignment coils.

The magnet is of the closed magnetic circuit type, it is made in three parts which can be split or reassembled using a custom made machine; guide pins are employed to ensure precise reassembly. It has an air gap of 25 mm with an inner diameter of 390 mm. The magnet is made using segments of Samarium Cobalt with thin NiFe alloy sheets inserted between the segments to reduce the temperature dependence of the generated field. The horizontal position of the magnet, and its angle about horizontal axes, can be adjusted using in-vacuum motors which can be switched off without affecting the adjustments. The system has been designed to be compact, has a high stiffness and a low thermal dissipation.

Recently, they attained less than ±10 μmstraightness errors at coil position in a 20 mm range. They intend to make their first measurements of the Planck constant in March 2017 with the aim of producing a result with a relative standard uncertainty near 100 parts in 109 by April 2017.

The KRISS Kibble balance has four full time staff with part time support on interferometry and voltage measurement. They are funded at a level of 0.6 M$/year for the present stage of the work (2015-2017).

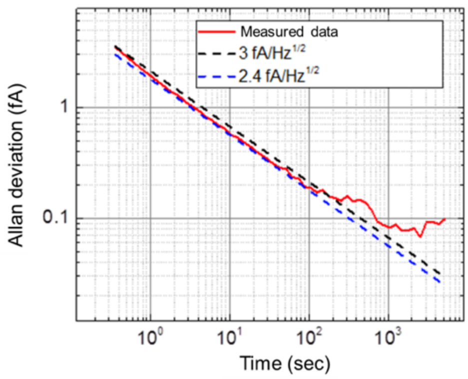
1.2 Quantum Metrology Triangle

Contact: Dr. Wan-Seop Kim(ws2kim@kriss.re.kr)

KRISS has launched the quantum metrology triangle (QMT) project last year to close the QMT in the next 10 years within an uncertainty of 0.02 x 10^{-6}. The strategy for our project is to minimize the environmental noises by placing all the three quantum standard devices (Josephson voltage standard (JVS), quantum Hall resistance (QHR) and single electron tunneling (SET)) including a cryogenic current comparator in the same cryostat and to increase the signal-to-noise ratio by utilizing QHR arrays as well as developing a quantum-limited cryonull detector.

A ^{3}He/14 T cryostat, designed for integration of Single Electron Tunneling, Quantum Hall Resistance, Josephson Voltage Standard devices was installed to test the performance. The cryostat was fulfilled the required criteria for the QMT experiments such as cable insulation of 33 TΩ, magnetic field strength of 1 mT, stability of signal 1000 s and white noise level of 2.5 fA/Hz$^{1/2}$. All the 3 quantum devices will be installed in the cryostat and the performance of the devices will be tested in the next year.

^{3}He/14 T QMT cryostat (left) and insert (right)

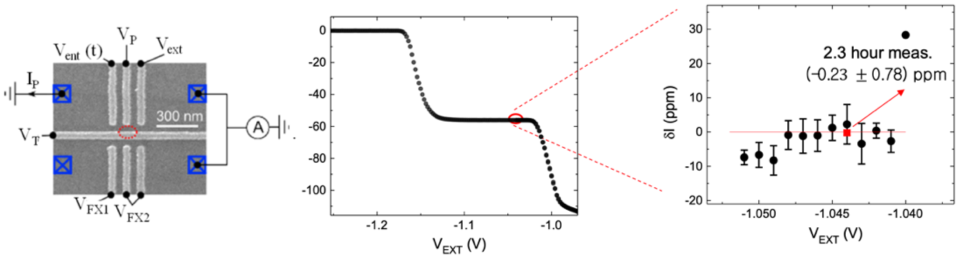


Noise measurement of cryostat cable installed

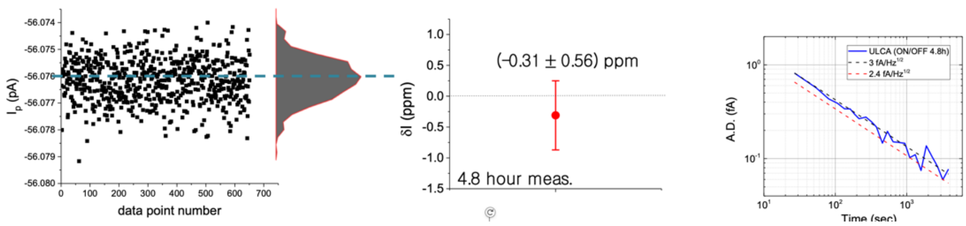
1.3 SET

Contact: Dr. Nam Kim (namkim@kriss.re.kr)

The gate-tunable electron pump showed a quantized current at Ip ~ 56.076 with a rf frequency of 0.35 GHz. We evaluated the plateau by high-precision measurement, which showed a good flatness for ΔV_{EXT} ~ 7 mV.



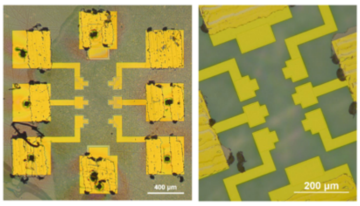
The relative uncertainty was obtained as ~0.56 ppm for ~5 hour measurement based on the ULCA system. The Allan deviation measurement gave the current noise level as ~ 3 fA/Hz$^{1/2}$



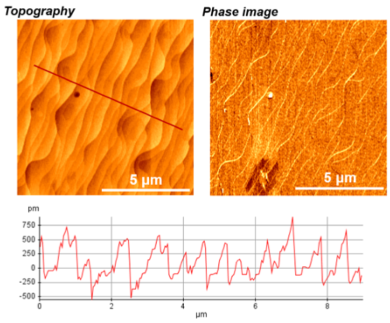
1.4 Graphene QHR

Contact: Dr. Jaesung Park (jspark99@kriss.re.kr)

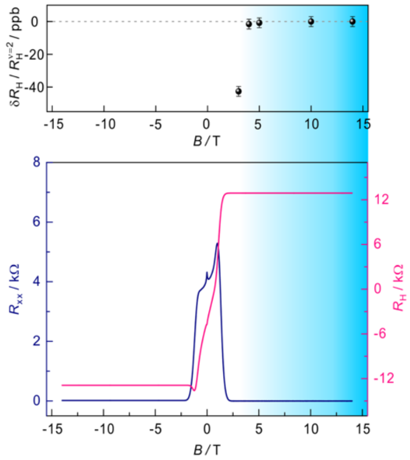
We are developing the graphene QHR standard for the practical realisation of DC QHR standard as well as the quantum impedance standard. KRISS has experimentally demonstrated that QHR standard can be realized at magnetic field down to 5 T and at temperature up to 4 K. The precisely measured value is equivalent to the nominal value of h/e^2 within the measurement uncertainty. We also believe that array of graphene QHRs can be utilized to improve the present DC current metrology.



OM images of Graphene QHR devices



AFM topography of Epitaxial graphene surface

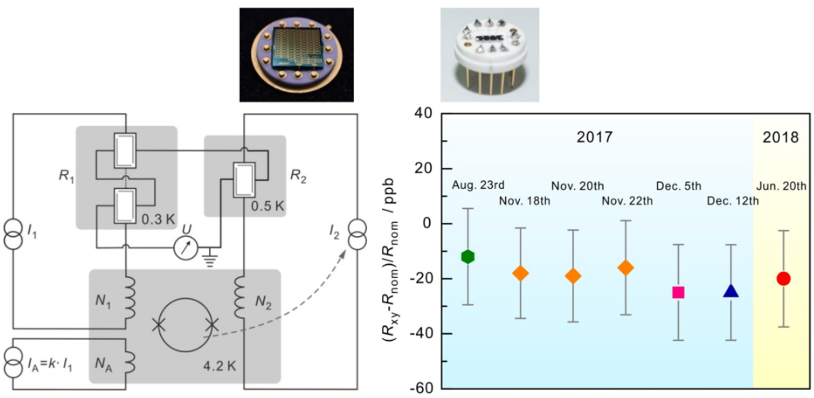


Magnetotransport & Precision measurements

1.5 Evaluation of QHR array

Contact: Dr. Dong-Hun Chae (dhchae@kriss.re.kr)

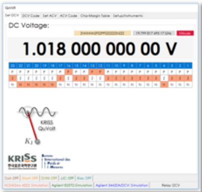
We have precisely measured the value of a 1 MΩ QHAR through a direct comparison with the QHR standard using a CCC resistance bridge with a relative measurement uncertainty of 17×10^{-9}. The 1 MΩ QHR array exhibits the invariant quantum nature through repeated thermal cycles even with classical interconnections. We are now working on an experiment on an ideal quantum mechanical current-to-voltage conversion with quantum Hall resistance array for small current measurements.

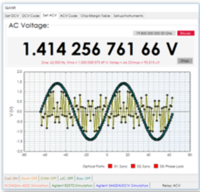


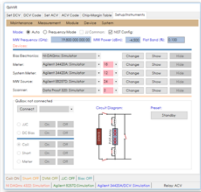
1.6 Development of KRISS QuVolt

Contact: Dr. Mun-Seok Kim (msk2003@kriss.re.kr)

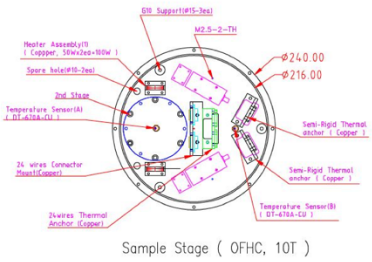
Three systems of the KRISS QuVolt (PJVS developed in KRISS) have been implemented for DCV calibration service, the KRISS Kibble balance, and the KRISS QMT.

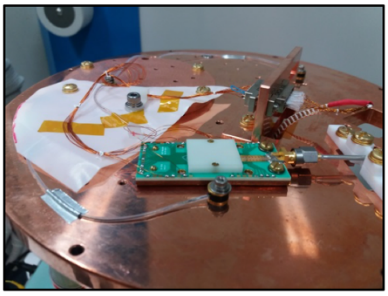






A CCR system has been developed for next generation of the KRISS QuVolt. A couple of 1.5-V PJVS chips will be installed to the CCR system for setup of quantum impedance bridge.



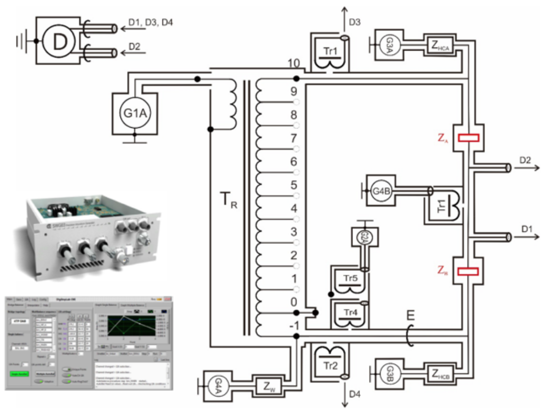


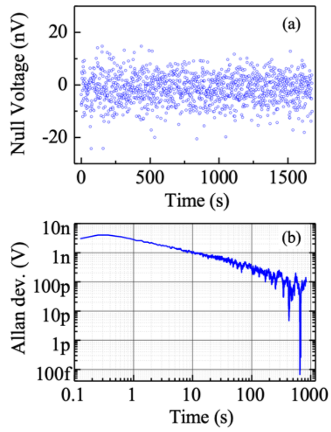
2. DC/LF/Magnetism Metrology

2.1 Impedance

Contact: Dr. Dan Bee Kim (danbeek@kriss.re.kr)

A high precision impedance bridge has been newly set-up. The bridge was developed by CMI, and it can be operated in either digitally assisted or fully digital modes. Under the 4TP digitally assisted configuration, the ac resistance and the capacitance standards were compared for the 10 : 1 ratio in the impedance range of 1 Ω ~ 1 MΩ and 1 pF ~ 1 μF, respectively. The bridge can be operated in the frequency range of about 10 Hz ~ 20 kHz. The aiming uncertainty level of the bridge is about 10^{-8} at the best.



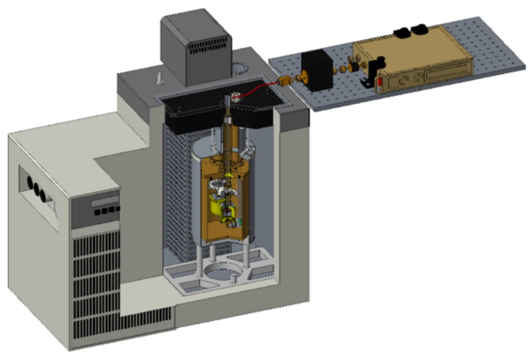


3. RF Metrology

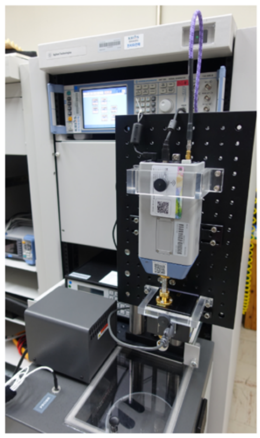
3.1 RF power

Contact: Dr. Jae-Yong Kwon (jykwon@kriss.re.kr)

We are currently evaluating the uncertainty of W-band waveguide microcalorimeter with a wide band RS. D-band (110 GHz ~ 170 GHz) waveguide microcalorimeter has been developed and their basic performance is under evaluation.



W-band waveguide calorimeter



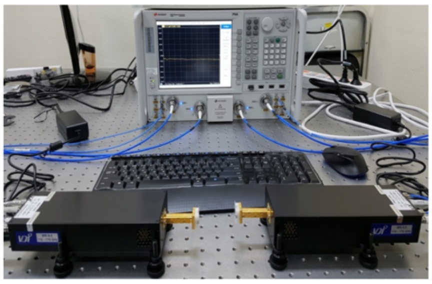
D-band waveguide calorimeter

3.2 Impedance

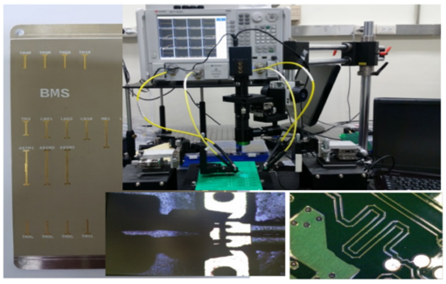
Contact:Dr. Young-Pyo Hong (youngpyo.hong@kriss.re.kr)

(1) Uncertainty estimates for traceable scattering coefficient measurements of waveguide devices in the frequency range 110 GHz to 170 GHz have been initiated. Precision dimensional measurements of the quarter-wavelength shim are achieved to establish traceability to the International System of units (SI) for standard line as a calibration standard in VNA measurements.

(2) Established broadband on-PCB measurement system for planar differential impedance standards. On-PCB differential standards suitable for calibrating and verifying differential S-parameter measurements of PCB interconnects have been designed and tested. The standards, implemented in a on-PCBs, were tested by means of mixed-mode multi-line TRL calibration. Embedded DUT is characterized after fully de-embedding the effects of the test fixtures including GSSG probes.



Waveguide Impedance Measurement System (110 GHz ~ 170 GHz)

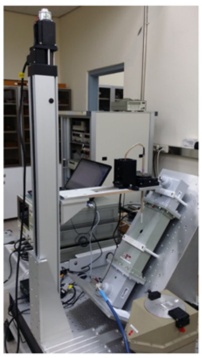


Planar Differential Impedance Measurement System (100 MHz ~ 40 GHz)

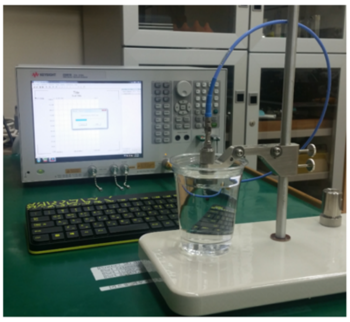
3.4 Field Strength

Contact: Dr. Tae-Weon Kang (twkang@kriss.re.kr)

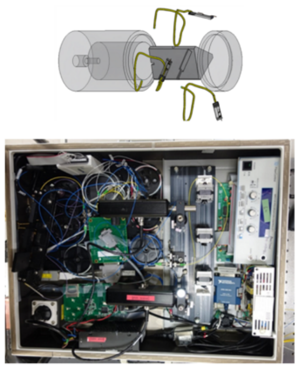
Research on the specific absorption rate (SAR) in the human head and body from wireless communication devices has been launched this year. Field generation systems up to 3 GHz were implemented to measure the diode compression point and air sensitivity of an SAR probe. To measure the dielectric constant and conductivity of human tissue simulating liquids a 20-GHz commercial liquid permittivity measurement fixture was installed. We also have developed field probing system based on electro-optic technique, which shows decent sensitivity (~30 mV/m) and broad bandwidth (up to 18 GHz) to extend the SAR application.



Field generation system for SAR probe calibration



Liquid permittivity measurement

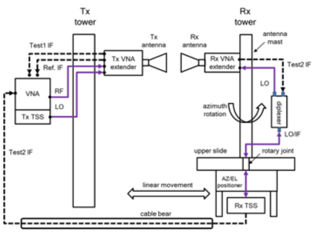


3-axis EO field probe (top) EO field probing system (bottom)

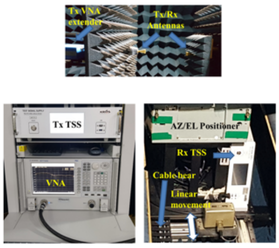
3.5 Antenna

Contact: Dr. No-Weon Kang (nwkang@kriss.re.kr)

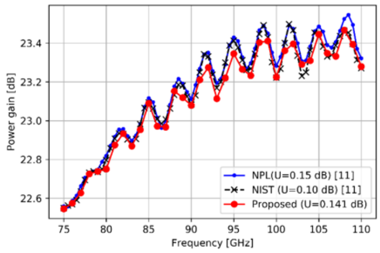
The conventional antenna gain measurement system is improved to W-band. The mixer and the LO are installed separately in the transmitter. The uncertainty analysis is completed.



W-band System



Photos of W-band System



Measurement result

4. KC and MRA

4.1 Comparison Activities since 2017

CCEM.RF-K5.c.CL (Reflection coefficient / S parameters in 3.5 mm connectors): in progress

CCEM.RF-K23.F (Ku-band antenna gain, PL: NIST): measurement completed.

CCEM.RF-K22.W (Noise in waveguide between 18 GHz and 26.5 GHz): Approved for equivalence in 2016

APMP.EM-K2 (High Resistance Comparison, PL:KRISS): Draft B.

APMP.EM.BIPM-K11.3 (10 V and 1.018 V DC VOLTAGE, PL:KRISS): Completed. Report published.

APMP.EM.BIPM-K11.4 (1.018 V and 10 V Standards bet. VMI and the KRISS, PL:KRISS): Completed. Report published.

APMP.EM.BIPM-K11.5 (10 V and 1.018 V DC VOLTAGE): measurement completed

APMP.EM-K12 (AC-DC Current Transfer Standards): Draft A.

APMP.EM-S13 (DC magnetic flux density bet. NML-SIRIM and KRISS, PL:KRISS): Completed. Report published.

APMP.EM-S14 (Earth-level DC magnetic flux density, PL:VNIIM): Completed. Report published.

SIM.EM.RF-K5.b.CL (Scattering coefficients by broad-band methods): in progress

CCEM.RF-K26.CL (Attenuation at 18 GHz, 26.5 GHz and 40 GHz): in progress

(written by Hyung-Kew Lee and No-Weon Kang, 2019. 03. 25.)