KRISS Korea Research Institute of Standards and Science

Progress Report of KRISS Electromagnetic Metrology

(29th meeting of the CCEM, March 2015)

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 2013).

1. Electrical Quantum Standards

1.1 Watt balance

Contact: Dr. Kwang-Cheol Lee (kclee@kriss.re.kr), Dr. Jinhee Kim (jinhee@kriss.re.kr)

The KRISS watt balance project started at 2012. The laboratory for the project was built at 2014 in the underground building. The gravity map before the installation of the watt balance system was surveyed. The linearity of a prototype of the piston guide was less than 1 μm at 40 mm travel distance. The main system including a translation guide, weighing cell and magnet stage was fabricated. The permanent magnet assembly, which is in production at a German company, will be delivered in 2015. Our aim is to start the measurement in 2016 and report the result in 2017.

1.2 Single electron pumping

Contact: Dr. Nam Kim(namkim@kriss.re.kr), Dr. Myung-Ho Bae (mhbae@kriss.re.kr)

We have investigated the accuracy dependence of a single-electron pump on the confinement-potential shape of a quantum dot (QD) pump. A uniquely designed QD, which employs multiple gates to control the shape of the QD potential well, is utilized for electron pumping. It has been observed that the accuracy of the pump can be dramatically enhanced by achieving smaller QD size and greater decoupling from the electrodes, which is supported by the so-called decay-cascade model. We performed a precision measurement of the pump device. In an optimally tuned condition, driven with a sinusoidal-waveform microwave at f = 0.95 GHz, B = 11 T, and T = 0.3 K, the relative deviation of the pump current from ef, $\delta I_p/ef \equiv (I_p - ef)/ef$ was measured to be (-0.92 ± 1.37) ppm. Our experiment reproduces the current quantisation accuracy of a previous measurement of a single-parameter pump, but in a device fabricated using very different geometry, thereby indicating that accurate single-parameter pumping is insensitive to device details. Our result is an important step in demonstrating that accurate charge pumping in single-parameter pumps is a universal phenomenon, which can be reproduced in another structure. [Ref. PRB 2014, Metrologia 2015].

1.3 Noise Thermometry

Contact: Dr. Yonuk Chong (yonuk@kriss.re.kr)

Shot noise thermometry setup using metallic tunnel junction is now operating from room temperature down to 0.3 K in a He-3 cryostat. The temperature range is to be extended down to below 100 mK using dilution refrigerator. A compact system based on crycooler is set-up down to 3 K for practical use. Pulse-driven AC-Josephson standard-based arbitrary waveform synthesis system is now operating with output voltage up to 100 mVrms, and over 100 dBc signal to distortion ratio. This system is aimed to be used as a quantum calculable noise source.

2. DC/LF/Magnetism Metrology

2.1 Impedance

Contact: Dr. Dan Bee Kim(danbeek@kriss.re.kr), Dr. Wan-Seop Kim(ws2kim@kriss.re.kr)

Digitally assisted impedance bridges have been set up to link the unit of farad to DC QHR at KRISS, where the bridges developed by INRIM mainly consist of a digital-sine wave generator, a resistance ratio bridge and a quadrature bridge. The sine wave synthesizer employs a commercial digital-to-analogue converter (DAC) board and is operating at a frequency of 1541 Hz. Two AC standard resistors with a nominal value of 10^3 kΩ (4xR_K) are calibrated using an 8:1 coaxial resistance ratio bridge and a Bifilar resistance standard with 12.9 kΩ (R_K/2) linked to the DC QHR established at KRISS. Calibration of the two 1 nF capacitance standards performed using the two 10^3 kΩ resistance standards and the quadrature bridge shows a good agreement with the step-up results of the capacitance standard of 10 pF within measurement uncertainty of 1 ppm.

2.2 New Electrical Power Standards

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

We have built an electrical-power standard based on digital sampling technique. The system can generate voltage and current signals of which RMS amplitudes and relative phase are fully adjustable. The signals are applied to a power meter under test, and are transformed to 1-V level voltage signals using an inductive voltage divider, a current transformer, and an AC shunt for sampling measurements. The system equips a single sampler with an AC multiplexer to measure signals from voltage and current channels in a single sampling run. After the sampling measurement, the RMS amplitudes and the relative phase for the transformed signals are obtained by DFT analysis on the sampled data. We estimate uncertainty for sampling of 1-V level signal is much less than 1 parts in 10^6. Now, we are developing a quantum power standard adopting a programmable Josephson voltage standard to attain uncertainty less than 5 μW/VA. In CPEM 2014, we proposed a new measurement procedure for quantum power standard, where 'differential' quantum sampling is used for absolute measurement and 'normal' sampling is used for ratio and phase measurement. The sampling and switching techniques developed in this work can be used for ac measurement applications including transformer evaluation and impedance bridge setup.

2.3 Magnetism

Contact: Dr. Po Gyu Park(pgpark@kriss.re.kr)

The automatic compensation of the external variation and a precise reproduction of magnetic flux density(MFD) were constructed for MFD standard at the base of Cs atomic magnetic resonance(AMR) and Cs-^{4}He AMR magnetometer. This system was installed at nonmagnetic laboratory and away from the artificial MFD noise sources. The apparatus consists of a Helmholtz coil with three orthogonal components, 2 current sources for compensation of a horizontal permanent MFD, current source for the vertical standard MFD reproduction, CS-AMR based MFD controller for compensation of MFD variation and Cs-^{4}He standard magnetometer for reproduction of MFD with vertical components. The variations of the external MFD are automatically compensated within 0.1 nT/h by a Cs AMR field controller. The vertical Helmholtz coil reproduces a dc MFD that is uniform to better than 0.5 nT within ± 5 cm around its center. The stable and uniform MFD is maintained in the range of (5 ~ 120) μT with 1 nT uncertainty(*k*=2. C.L 95%) respectively. This system can provide accurate calibration of magnetometer, measurement of coil constant in comparison with Cs-^{4}He standard magnetometer, and the experiments related to low MFD. We have a plan to improve the uniformity(less than 0.2 nT, ± 5 cm) of a Helmholtz coil using a several moment coils.

3. RF Metrology

3.1 RF power

Contact: Dr. Jae-Yong Kwon(jykwon@kriss.re.kr), Dr. Tae-Weon Kang(twkang@kriss.re.kr)

The measurement setup of a new type-N coaxial microcalorimeter and the evaluation of the microcalorimeter were completed. Preliminary results of evaluation and design were presented at CPEM 2014 Rio de Janeiro, Brazil. The evaluation of transfer standards is in progress.

3.2 Impedance

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

Preliminary measurements of the broad and narrow wall dimensions of the apertures of the WR-15 waveguide standard shim were obtained using 3-D coordinate measuring machines (CMMs). The measurement setup of traceable scattering coefficient measurements of waveguide is in progress in the frequency range 50 GHz to 75 GHz.

3.3 Noise

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

A noise temperature standard has been established with the expanded uncertainty of 0.13 dB in the frequency range of 75 GHz to 105 GHz. For this purpose, a waveguide noise measurement system consisting of two standard noise sources and a waveguide radiometer has been developed.

3.4 Antenna characteristics

Contact: Mr. Jeong-il Park(jipark@kriss.re.kr), Dr. No-Weon Kang (nwkang@kriss.re.kr)

Evaluation of K-band (18 GHz ~ 26.5 GHz) antenna gain is completed by extrapolation technique based on three antenna method. The expanded uncertainty (k = 2) of antenna gain is 0.14 dB in the range of 18 GHz to 26.5 GHz.

3.5 Field strength

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

The upper frequency of the calibration and measurement capabilities for calibrating an electric field probe was extended from 18 GHz to 26.5 GHz. New mast made of epoxy glass was designed and constructed for calibration of the commercial probes. A standard field generation system consisted of a K-band horn antenna which was calibrated by three antenna method based on extrapolation technique and K-band TWT amplifier was implemented.

3.6 Pulse parameters

Contact: Dr. Dong Joon Lee(dongjoonlee@kriss.re.kr)
/Dr. Chihyun Cho(chihyun.cho@kriss.re.kr) / Dr. Joo-Gwang Lee(jglee@kriss.re.kr)

Pulse waveform metrology based on electro-optic sampling was started since 2013. The fast pulse measurement system associated with a femtosecond laser up to 50 GHz and 100 GHz has been built in 2013 and 2014. We are currently evaluating the uncertainty of the 50 GHz pulse waveform system to provide traceability chain for high speed waveform. (Dr. Dong Joon Lee)

Evaluation of digital parameters such as EVM and Eye pattern are developing to link the traceability chain. Recently, the EVM for W-CDMA has been evaluated and reported in CPEM in Brazil. In addition, calibration methods for real-time and sampling oscilloscopes are developing. First, the systematic errors such as time base and channel mismatch are corrected, and then the system response of the scope will be calibrated using the developing pulse standard. (Dr. Chihyun Cho, Dr. Joo-Gwang Lee).

4. KC and MRA

4.1 Comparison Activities since 2013

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): Draft A
APMP.EM-K2 (High Resistance Comparison, PL:KRISS): in preparation of Draft A.
APMP.EM.BIPM-K11.3 (10 V and 1.018 V DC VOLTAGE, PL:KRISS): in preparation of Draft B.
APMP.EM.BIPM-K11.4 (1.018 V and 10 V Standards bet. VMI and the KRISS, PL:KRISS): Approved
APMP.EM.BIPM-K11.5 (10 V and 1.018 V DC VOLTAGE): measurement completed
APMP.EM-K12 (AC-DC Current Transfer Standards): measurement completed.
APMP.EM-S13 (DC magnetic flux density bet. NML-SIRIM and KRISS, PL:KRISS): Approved
APMP.EM-S14 (Earth-level DC magnetic flux density, PL:VNIIM): Approved
SIM.EM.RF-K5.b.CL (Scattering coefficients by broad-band methods): in progress

(written by Po Gyu Park and No-Weon Kang, 2015. 03. 07.)