Progress Report of KRISS Electromagnetic Metrology

(30th meeting of the CCEM, March 2017)

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 2015).

1. Electrical Quantum Standards

1.1 Kibble Balance

Contact: Dr. Kwang-Cheol Lee (kclee@kriss.re.kr), Dr. Jinhee Kim (jinhee@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), Dr. Nam Kim(namkim@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 x10^{-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 quantumlimited cryo-null detector.

KRISS has already established two arms of the QMT, JVS and QHR, and has been developing single electron pumps for the realization of the ampere based on the redefinition of the SI unit "Ampere". Single electron pumps of KRISS proved to produce quantized current levels of 100 pA with an uncertainty of about 2×10^{-6}. A new SET current measurement system is currently under development to increase the generated current level as well as to improve measurement uncertainty.

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)

The digitally assisted impedance bridges of linking the unit of farad to DC QHR at KRISS have been kept evaluated for their improvements in the measurement uncertainties. Especially, the noise for the digitally assisted quadrature bridge has been greatly reduced, and now the type A uncertainty is in the order of 10^{-8} – 10^{-7}. In addition, a new calculable AC-DC resistance standard of 12.9 kΩ has been purchased from CMI in order to replace our ten-year-old calculable standard, and preliminary tests are in progress.

For the capacitance measurements in the high frequency range up to 1 MHz, a dual source bridge was set up in the two-terminal-pair configuration using two Fluke 5720A calibrators as voltage sources. The capacitance ratios of 1 : 1 and 10 : 1 were measured for 1, 10, 100, 1000 pF capacitor standards. The results were compared with those of a commercial ratio transformer capacitance bridge for the low frequency of 1 kHz and the Z-matrix method for the high frequency of 1 MHz and showed good agreements within 10^{-6} – 10^{-5}.

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)

AC magnetic flux density(MFD) standard system was developed to calibrate magnetometers, magnetic sensor and field coils in the frequency range of 1 Hz to 50 kHz. This system was installed at nonmagnetic laboratory and away from the artificial magnetic noise sources. The standard of AC MFD is maintained in the range of (20 ~ 20000) nT with 0.3 % in the range of 1 Hz to 20 kHz and 1 % in the range of 20 kHz to 50 kHz uncertainty(k=2, C.L 95 %) respectively.

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 V-band waveguide microcalorimeter and the evaluation of the microcalorimeter were completed. Preliminary results of evaluation and design were presented at CPEM 2016 Ottawa, Canada. The evaluation of transfer standards is in progress.

3.2 Impedance

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

Precision dimensional measurements of both straight-section waveguide and 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. Uncertainty estimates (expanded uncertainty of 0.053 dB) for traceable scattering coefficient measurements of waveguide devices in the frequency range 75 GHz to 110 GHz have been achieved.

3.3 Noise

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

The measurement uncertainty of the noise temperature standard in the frequency range of 75 GHz to 105 GHz has been reevaluated to be 0.30 dB. The uncertainty includes connection repeatability of waveguide flanges of the rf input switch.

3.4 Field Strength

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

Standard field generation system by using waveguide is under development. The system use WR-2300 waveguide (0.32 GHz ~ 0.49 GHz). The correction factors between waveguide and micro-TEM cell by using transfer standard were compared. The results shows good agreement.

3.5 Pulse Parameters

Contact: Dr. Chihyun Cho (chihyun.cho@kriss.re.kr) / Dr. Joo-Gwang Lee (jglee@kriss.re.kr)/ Dr. Dong Joon Lee (dongjoonlee@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 100 GHz has been built. We use a calibrated 100 GHz photodiode for transfer standard pulse generation. The calibration methods for real-time and sampling oscilloscopes are developing. First, the correction method for time base distortion of sampling scopes has been developed and reported in CPEM in Canada. Recently, the channel mismatch correction method for real-time digital oscilloscopes is published on the Trans. MTT. Research is on-going to calibrate the system response of the scope using the EOS pulse standard.

Evaluation of digital parameters such as EVM for LTE and Eye pattern are developing to link the traceability chain.

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): Approved for equivalence in 2016
APMP.EM-K2 (High Resistance Comparison, PL:KRISS): Draft A.
APMP.EM.BIPM-K11.3 (10 V and 1.018 V DC VOLTAGE, PL:KRISS): 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
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, 2017. 03. 07.)