2020 Activities on DCLF & RF at NIM

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DCLF

Joule Balance

NIM participated in the first key comparison of realizations of the kilogram (CCM.M-K8.2019) piloted by BIPM. According to the final report, the relative standard uncertainties of NIM-2 joule balance was 4.49×10^{-8} with a relative difference from the Key Comparison Reference Value (KCRV) of 1.17×10^{-8}. NIM made its contribution to the calculation of the first consensus value for the dissemination of the kilogram, which has come into force on Feb. 1, 2021.

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Quantum Devices for Electrical Standards

The 4-V quantum voltage chip and 2-V PJVS chip are made. Dayem type niobium nano-SQUID with high transfer coefficient V_Φ is achieved. A second-order gradient SQUID current sensor with white flux noise of 4 μΦ0 /√Hz is achieved. We are making the SQUID current sensor based on the Nb/Al-AlOx/Nb SIS Josephson junctions now.

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PJVS and QHR

A liquid helium free dc PJVS operating on a cryo-cooler at 4 K or 10 K was developed. The type A uncertainty of dc voltage reference standard (1 V and 1.018 V) calibration is 3.6×10^{-9} V. A 7 V_{rms} ac PJVS with frequency up to 400 Hz was developed. the type A uncertainty of 3.6×10^{-7} was achieved when measuring a 7.07107 V rms sine wave generated by a calibrator at 400 Hz.

NIM participated the ongoing key onsite comparisons BIPM.EM-K12 in 2019. A new QHR standard system located in CHANGPING campus was used in this comparison. The comparison report has been approved.

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Calculable Capacitor

Interferometer improvement of calculable capacitor by adding the fiber coupled beam of the 633 nm iodine stabilized laser to the interferometer. We used double-checking optical layout to confirm the input beams coupling into the interferometer perfectly by comparing the free space optical setups to fiber coupling ones. The difference between the dissemination results for capacitance by using these two different beam paths is less than 3.0×10^{-9}. The standard uncertainty of reproducing 1 pF capacitance unit from the NIM's new calculable capacitor with the latest optimal hollow active auxiliary electrode is improved to 1.0×10^{-8}.

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Energy Metering with Big Data Analysis

An approach to detect inaccurate smart meters by means of big data analysis was developed. The preliminary results show that the time series-recurrence plot model successfully identified the inaccurate meters inside a target residential area with good accuracy. The mean under the curve (AUC) of receiver operating characteristic (ROC) is 0.82±0.07 and the mean AUC of the precision-recall curve (PRC) is 0.84±0.11. This model reaches equivalent or better performance than several conventional machine learning models.

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Comparison of 4TP Capacitance

The comparison of APMP.EM-S15 in four-terminal-pair 1 pF, 10 pF, 100 pF and 1000 pF capacitance at frequencies of 10 kHz, 100 kHz, 1 MHz and 10 MHz was completed. The participants include NIM, NPLI and NIMT. The draft B report of the comparison was released.

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Impulse Voltage

We promoted a hypothesis that oscillations are possibly caused by the resistor in the damped capacitive voltage divider which often serves as the load for impulse voltage generation. By computer simulations and experiments, we proved this hypothesis.

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Fiber-optic Current Sensor

Frequency response characteristics of the fiber-optic current sensor were further improved by eliminating the feedback delay caused by A/D convertor's pipeline. It is shown by the test results that the bandwidth of the sensor is higher than 100 kHz.

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High Voltage Standard Capacitor

A micro-displacement measurement system based on the charge coupled device (CCD) image recognition is developed and installed in a 350 kV high-voltage capacitor with compressed-gas coaxial cylindrical electrodes structure. This CCD is used to measure the relative displacements of the low and high voltage electrodes, so as to determine the voltage dependence of the capacitor.

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RF& MICROWAVE

Waveform Metrology for Millimeter-wave Digitally-modulated Signals

A novel frequency-domain measurement setup for generating and characterizing millimetre-wave digitally-modulated signals is proposed, which is based on the nonlinear vector network analyser (NVNA) architecture. Different form the traditional phase calibration approach using ultra-fast impulse signals traceable to sampling oscilloscopes and electro-optic sampling (EOS) systems, pulsed-RF signals have been confirmed applicable in this work as phase standards without the need of waveform characterization. 5G-oriented test scenarios at 28, 39, 43, and 70 GHz have been used for method validation, where a phase spectrum error of ±2 deg. for 64-QAM measurements with a modulation bandwidth up to 2 GHz has been confirmed reachable in practice.

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RF&MW Power

NIM completed the design and fabrication of WR-3 (220 GHz ~ 330 GHz) thermoelectric power sensor, power meter and microcalorimeter in 2020. They will work together as the power primary standard and provide the traceability of power measurement in the frequency range from 220 GHz to 330 GHz in China. The self-designed power sensor has low return loss (<-15dB) that can work as a transfer standard. The effective efficiency of such transfer standard, over the full frequency band, can be measured in the microcalorimeter. The measurement uncertainty is under evaluation.

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Noise Measurement

A noise measurement method for microwave devices based on four reflection coefficients and iterative method is proposed. This method reduces uncertainties caused by system instability and temperature,

improves measurement efficiency, and lowers measurement cost by replacing the impedance tuner with mismatched loads. A novel genetic algorithm based calculation method for noise parameters is proposed, whose objective function is constructed by taking the noise figure error into consideration. It improves the measurement accuracy of minimum noise figure and optimum reflection coefficient magnitude when selected reflection coefficients are limited in one area of Smith chart, and improves the calculation efficiency in statistical analysis. The validity of proposed method is confirmed for the 1-40 GHz frequency range, with a measurement uncertainty lower than 0.25 dB.

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The Dielectric Properties Measurement of Materials

A Fabry-Perot quasi-optical open resonator was developed in NIM for the characterization of dielectric properties of materials in the millimetre-wave frequency range. The Gaussian beam theory was used to establish an inversion model for extracting the complex permittivity. Owing to its high quality factor, the open resonator was especially suitable for the accurate measurement of low-loss materials. A de-embedding algorithm was proposed for measuring the anisotropic properties of multilayer materials, such as liquid crystals. The resonator can operate at 75GHz~110 GHz at the moment and the measurement uncertainty of the real part of permittivity is lower than 1%.

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E-field strength transfer probe below 1 GHz

An electric strength transfer probe below 1GHz has been developed in NIM. Dr. Juan Carlos Mateus Sánchez from Inmetro joined in the project. The probe can transfer the standard E-field strength from uTEM Cell to GTEM Cell from 9 kHz up to 1 GHz (even higher), and the weakest E-field strength can be 2 V/m. It is much better than the transfer probe TFS 11 imported over 18 years ago. The new transfer probe is quite compact. The probe is powered by a rechargeable battery. The output of the probe is linked to a USB-like receiver via an optical cable, shown below. A notebook computer can be used to read the results.

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Antenna Group Delay Measurement

An antenna group delay measurement method is proposed based on antenna extrapolation range using the three-antenna method and the space scan technique. This method can minimize the error due to multiple reflections between the antennas during the group delay measurement. In this method, antenna group delay is measured as a function of distances using a three-antenna extrapolation method, and then the group delay is determined by averaging a set of measured GD values according to a derived multiple-reflection error model. The method is validated for the (1575.42-1591.42) MHz frequency range, with a measurement uncertainty lower than 0.15 ns (k=2).

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Antenna Pattern Measurement

Sleeve dipole probe antennas and loop probe antennas with less than ±0.1 dB of asymmetry specification in the azimuth plane pattern could be measured in NIM 3m-anechoic chamber. These probe antennas were mainly used for ripple test of OTA test sites. Low dielectric constant support structure was adopted for positioning the probe antennas, and laser collimator was used for alignment. The time gate method was introduced to suppress the reflections of the surrounding absorbers. The probe antennas of several manufacturers with frequency range [0.4, 6]GHz are measured and the measurement uncertainty is under evaluation.

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