Progress Report on Electrical Metrology at the PTB between 2023 and 2025 on the Occasion of the 34th Meeting of the CCEM

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1. Electrical Quantum Standards

1.1 Josephson Voltage Standards

PTB is working on further development and improvement of the Josephson Arbitrary Waveform Synthesizer (JAWS) based on pulse-driven Josephson junction series arrays. The fabrication technology for the highly integrated JAWS circuits is based on stacked Josephson junctions with up to 5 junctions and Nb_xSi_{1-x} barriers. During the last years, the main efforts at PTB concentrated on increasing the output voltage and frequency, as well as reducing the complexity of JAWS setups. To this end, new lumped element Wilkinson power dividers were developed and optimized by RF simulations. Additionally, the standard fabrication process was further improved by better edge insulation of the junction stacks using atomic layer deposition of the dielectric layer (SiO_2). Finally, first arbitrary waveforms were successfully generated from 1 to 10 GHz with up to 3000 Josephson junctions integrated into a newly developed RF diplexer structure. (Oliver.Kieler@ptb.de, Johannes.Kohlmann@ptb.de)

The optically driven JAWS system at PTB was advanced by using custom-designed multi-layer printed circuit boards, which enable closer arrangement of the JAWS chips to improve integration and performance. Optical amplifiers were implemented to enhance optical power, and various photodiode carrier chip designs and Josephson junction arrays were tested to improve performance. Using passive optical power splitters and variable attenuators, two Josephson arrays comprising in total 6000 junctions were optically driven by four photodiodes via two independent optical pulse channels. An output signal amplitude of 35 mV RMS was achieved while harmonics in the amplitude spectrum were suppressed by more than 96 dBc. The system was expanded with additional optical channels and 1:4 optical splitters to further increase the output voltage. (Oliver.Kieler@ptb.de, Marco.Kraus@ptb.de)

PTB has started a cooperation with NMIA to develop an SI traceable calibration technique for thermal voltage converters, based on measuring their AC-DC transfer differences by using an AC quantum voltmeter (AC-QVM). Preliminary measurements at frequencies from 10 Hz to 3 kHz demonstrate agreement with conventional characterizations of better than 1 µV/V. Further investigations are necessary to examine possible interference between the AC-DC measurement and the AC-QVM system. This work aims at measurement uncertainties at the level of 0.1 µV/V. (Ralf.Behr@ptb.de)

PTB has started a cooperation with INTI to develop a new method for characterizing multi-tone signals by measurements with an AC-QVM. Using a four-period signal from the programmable Josephson voltage standard (PJVS), the previous problem of missing short portions of the signal measured due to the transients was solved. To validate the method, a direct comparison with a pulse-driven Josephson voltage standard (JAWS) on multitone signals was carried out for the first time. The method was confirmed at 100 mV-level and at 625 Hz. Furthermore, the potential of the new 'seamless' sampling method was demonstrated by spectrum measurements. (Ralf.Behr@ptb.de)

PTB as a member of a dedicated CCEM working group participated in the finalization of the BIPM comparison protocol for AC Josephson voltages (BIPM.EM-K10). Also, further pilot studies were carried out within a three-weeks visits to the BIPM in 2023 and 2024 in which different technical implementations of the calibration of AC voltages according to the protocol were investigated. In 2024, very good results were achieved with a new bias current source in the Josephson system of BIPM, supporting the start of BIPM on-site comparisons. (Ralf.Behr@ptb.de)

In an indirect comparison the four-terminal-pair Josephson impedance bridges of PTB and METAS (the only two bridges of this kind existing) have shown excellent agreement. In combination with impedance standard devices based on the AC quantum Hall effect, as being developed at PTB from graphene, these bridges enable directly linking the capacitance unit to the quantum Hall effect. Remaining challenges like AC losses, which need to be quantified and/or controlled, are currently tackled in close collaboration with METAS. Influences of the quantum Hall resistor device geometry are currently under investigation, using established and newly developped methods for measuring longitudinal impedances. (Stephan.Bauer@ptb.de)

In collaboration between the PTB and the Max-Planck-Institute for Nuclear Physics (MPIK), the application of ultra-stable low-noise Josephson voltage sources aims at the improvement of Penning trap experiments. The development of a compact 80-V PJVS has advanced regarding user-friendliness for routine operation. First experimental results were published, reporting an improvement by a factor of 2 in the axial frequency stability of a trapped $^{9}Be^{3+}$ ion. Furthermore, PTB has advanced the extension of a current bias source for the four 20-V PJVS arrays for output voltages between -80 V and +80 V. (Luis.Palafox@ptb.de)

PTB supported CERN in the characterisation of their newly developed digitizer HPM7177 using a 10-V PJVS. CERN developed the digitizer to fulfil the higher performance requirements for the high luminosity upgrade of the large hadron collider (HL-LHC). The practically noise-free voltages from the PJVS were used to characterize two units of the digitizer to study the stability over 12 hours and to study $1/f$ noise. Voltage ramps, both by varying the number of junctions biased and with finer steps achieved by modifying the microwave frequency allowed measuring the nonlinearity. In addition, three level waveforms were employed to determine the settling time. The results confirmed that the HPM7177 digitizer complies with the requirements for the highest HL-LHC accuracy class. (Luis.Palafox@ptb.de)

1.2 Single-Electron Transport and Quantum Current Standards

PTB continued the development of single-electron pumps as a quantum current standard. In collaboration with the University of Latvia, PTB developed and validated a scaling relation, which allows to access high-frequency limits for operating single-electron pumps. Utilizing the scaling relation, multiple measurements – each covering a parameter range limited by measurement precision – can be combined into an empirical scaling curve. High-fidelity single-electron detection and counting experiments at PTB were used to validate the relation over a wide parameter range spanning multiple orders of magnitude. The results underpin the robustness of the exponential selectivity of tunneling for applications as a quantum standard. By this technique, device platforms can now be benchmarked to identify the maximal operating frequency and thereby the maximal quantized current output. (Niels.Ubbelohde@ptb.de)

PTB has confirmed in proof-of-principle experiments that the inherent Bloch oscillations of superconducting Josephson junctions with tens of nm size can be synchronized to external GHz-frequency signals. This long-sought-after effect leads to coherent transport of Cooper pairs and manifests itself as a series of steps in current-voltage measurements, which are separated by $2ef$, with e the elementary charge and f the frequency of the GHz-signal. A direct demonstration of Bloch oscillations was achieved in a dc-SQUID of ultrasmall Josephson junctions. By capacitive coupling to an external drive with frequency of up to 6 GHz, steps at currents up to $I = 2e\times 6$ GHz ≈ 2 nA were demonstrated. These so-called dual Shapiro steps are the quantum dual to the steps used in the Josephson voltage standard. By applying a pulsed synchronization signal, an asymmetric pattern of two times wider steps was achieved. Present investigations focus on increasing the measurement precision and evaluating the potential of the device for a current standard. (Sergey.Lotkhov@ptb.de, Lukas.Gruenhaupt@ptb.de)

1.3 Quantum Hall Effect

The fabrication of graphene quantum Hall resistors (QHR) was advanced by the integration of flip-chip contact technology with the lithography and doping processes established at PTB. This technology combines compact packaging with advanced encapsulation and electrical shielding options. Unlike other methods relying on polymer encapsulation or glass dome sealing in combination with wire bonding, the new approach enables stable electric contacts without vibration-prone wires and includes epoxy encapsulation. A European patent has been applied for, and the application has recently been extended to the USA. (Mattias.Kruskopf@ptb.de, Oliver.Kieler@ptb.de)

The long-term stability of graphene QHR devices is being studied, including investigations into the effects of different device encapsulation techniques such as polymer and flip-chip encapsulation as well as encapsulation with AlO_x using atomic layer deposition (ALD). Preliminary results show that flip-chip and ALD encapsulation are the most promising candidates compared to encapsulation with polymer. (Mattias.Kruskopf@ptb.de, Klaus.Pierz@ptb.de, Teresa.Tschirner@ptb.de)

For the realization of QHRs based on epitaxial graphene reliable doping methods are required to reduce the intrinsically very high electron concentration to a value optimized for operation in low magnetic fields. PTB has successfully tested simplified doping layer structures deposited on epitaxial graphene with a reduced number of layers and process steps from the previously established 5 layers to 3 and even 2 layers. High accuracy measurements show comparable excellent metrological quality for all types of devices and long-term stability over two years. Relative deviations of the quantum Hall resistances R_{xy} from $R_K/2$ were within the combined uncertainty 3 nΩ/Ω ($k = 2$) of the measurement. PTB will use these simpler doping schemes for the fabrication of future graphene QHR. (Teresa.Tschirner@ptb.de, Mattias.Kruskopf@ptb.de)

PTB has fabricated and evaluated hole-doped graphene QHRs. These *p*-type QHRs were realised based on epitaxial graphene by applying the concentration-dependent molecular doping method successfully used for the realization of high-quality *n*-type QHRs. The Hall resistance curves of both charge carrier polarities show symmetric behavior. Measurements show excellent comparable quantization over the complete quantum Hall resistance plateaus starting at $B = 5$ T and an agreement of 2 nΩ/Ω with the nominal resistance value $R_K/2$ for individual measurements at $T = 4.2$ K against a calibrated 100 Ω reference resistor. This corroborates the universality of the quantum Hall effect and underpins the future role of graphene QHRs in resistance metrology (Teresa.Tschirner@ptb.de, Mattias.Kruskopf@ptb.de).

To address the increasing demand for cryocooler-based quantum metrology systems being independent of liquid helium supply, a QHR system based on a pulse-tube cryocooler hosting a graphene QHR device was set up and characterized. The system achieves temperatures down to 2.6 K. Comparison measurements with QHR devices operated in traditional liquid helium cryostats show that the results are comparable in terms of accuracy and reproducibility. Also, the development of a cryogenic current comparator operated in a pulse-tube cryocooler is being pursued in collaboration with industry partners. (Mattias.Kruskopf@ptb.de)

To support the international transition from GaAs- to graphene-based quantum Hall resistance standards, PTB is participating in the new BIPM Task Group "CCEM-TG-Graphene", which aims at developing guidelines for the future use of graphene quantum Hall resistance standards in metrology. (Hansjoerg.Scherer@ptb.de)

The quantum anomalous Hall effect (QAHE) in magnetically doped topological insulator materials is investigated with the aim of utilising it for next-generation quantum Hall resistance standards that can be operated without an external magnetic field. In cooperation with the University Würzburg, PTB has performed Hall resistance measurements on devices made from vanadium-doped $(BiSb)_2Te_3$. The investigations showed that the relative deviation of the Hall resistance from the von Klitzing constant at zero external magnetic field is within the relative standard measurement uncertainties of a few nΩ per Ω in the transport regime of zero dissipation, corroborating the universality of the quantum Hall effect. Ongoing work focussing on the exploration of advanced QAHE devices operational at elevated critical temperatures and currents is being carried out in frame of the project "QuAHMET" in the European Partnership on Metrology (EPM). (Hansjoerg.Scherer@ptb.de, Mattias.Kruskopf@ptb.de)

1.4 Metrology for Quantum Technologies

PTB continues to be a partner in multiple national and European research projects on superconducting quantum circuits. In these activities PTB has achieved state-of-the-art performance for Josephson traveling-wave-parametric amplifiers (TWPA) and has expanded its experimental capabilities to perform reliable measurements of TWPA characteristics such as gain, bandwidth and added noise. An additional focus of PTB addresses superconducting qubit technology, i.e. their readout and control. Here, a superconducting qubit was used as a power sensor for fW powers at temperatures on the order of 20 mK. Further work is underway to expand the measurement methodology and perform consistency checks between different methods using superconducting qubits. Since 2024 PTB coordinates the EPM project 'MetSuperQ', which aims at developing a robust framework for the characterization and evaluation of superconducting single- and multi-qubit devices. Within this project, a first European round robin of qubit performance measurements will be carried out between different partners. (Lukas.Gruenhaupt@ptb.de)

PTB developed a cryogenic electro-optic sampling (EOS) setup that allows for the measurement of microwave signals at arbitrary positions on cryogenic device. Using this setup, the time-domain response of ultrafast cryogenic photodiodes and the electrical reflection coefficient, i.e., the S_{11} scattering parameter, in a superconducting transmission line have been extracted. Moreover, a Josephson Arbitrary Waveform Synthesizer (JAWS) was used to generate quantum-accurate voltage signals, which have been measured with the EOS setup. This allows for the calibration of the EOS response, yielding traceability of the microwave measurements to a quantum standard. Finally, JAWS output frequencies around 1 MHz could be directly measured in the time domain and at a temperature of 4 K using the EOS setup. (Mark.Bieler@ptb.de)

2. Voltage, Resistance, Current, AC/DC Transfer, and Impedance

Piloted by PTB, the EURAMET supplementary comparison on small direct current sources in the range from 100 fA to 1 nA, EURAMET.EM-S45 (EURAMET Project 1562), has been started in 2023. The travelling standard consists of an Ultrastable Low-Noise Current Amplifier (ULCA), a Zener voltage reference and a digital voltmeter. The stability of this travelling standard allows for combined expanded uncertainties below one part in 10^6 in the highest current range. So far, measurements have been performed by the pilot lab and by four participating NMIs. Experimental work at four more NMIs is still pending. According to the agreed schedule, the measurements will be completed in 2025. The final report will tentatively be available in 2026. (Martin.Goetz@ptb.de)

A calibration setup for current clamps for the current range from 10 mA to 10 A and at frequencies up to 500 kHz was developed to establish traceability of high RF currents through scalpels used in medical surgery. Special disc resistors with various resistance values were designed to accommodate the wide current range. The AC-DC transfer method is employed, enabling precise and traceable current measurements. Compared to the currently available calibration capabilities (CMCs), which only cover frequencies up to 100 kHz at 10 A, the new setup represents a significant enhancement. The development is in its final stages and is approaching its successful completion. (Andre.Mueller@ptb.de)

AC resistance standards based on a series-connection of commercial surface-mount device resistors were developed. Their AC-DC differences in the frequency range up to a few megahertz are precisely calculable and about four orders of magnitude smaller than those of conventional calculable resistors of the Haddad or Gibbings type. So far, this has been demonstrated for a nominal resistance value of 12.9 kΩ, but realizations of other nominal values are possible as well. The resistors allow the calibration of commercial precision LCR meters which have a maximum operating frequency of 2 MHz, but so far could not be calibrated with the desired precision. The development has the potential to boost the precision of LCR meters by up to three orders of magnitude and to enable new impedance metrology applications. To also enable the calibration of the capacitance range of LCR meters, a new type of calculable coaxial capacitor is currently under development. (Juergen.Schurr@ptb.de, Rolf.Judaschke@ptb.de)

In preparation of the planned international CCEM-K3 inductance comparison, inductance standards were investigated for their suitability as travelling standard. The focus of the experiments was on their behaviour when the ambient temperature changes during transport of the standards. In addition, simulated inductance standards developed at NIM were characterized with respect to their stability and dependence on the measurement conditions. (Florian.Beug@ptb.de)

3. Power and Energy

Two different areas exist for calibration and testing with high AC voltages at PTB. On the one hand, there is the area of voltage transformers with the measurands ratio and phase error and, on the other hand, high AC voltage with the measurands peak voltage and RMS voltage. In most cases, the latter was measured using compressed gas capacitors or capacitive dividers. As these measurement systems have different sources of traceability, but in principle have the same measurand, a comparison of the traceability results were undertaken. First, PTB´s standard voltage transformer system as well as PTB´s standard high voltage capacitors and the associated measuring instruments were traceably calibrated. Then a comparison measurement was carried out at voltages of up to 90 kV. It was shown that the scale factors of the systems determined in advance matched over the entire voltage range within a band of ±30 µV/V. This result confirms the correct traceability of the individual systems and will lead to an improvement of PTB´s CMCs for high AC voltages. Based on these results new measurement capabilities will be developed for voltage transformers at voltages up to 800 kV. (Johann.Meisner@ptb.de)

The AC power standard at PTB established in 1999 exhibits a measurement uncertainty of $5 \cdot 10^{-6}$ (k = 2) at 120 V and 5 A. It works in a fully synchronised operation mode, where the sampling frequency and generated signal frequency of the test voltages and test currents are derived from the same master clock. After 25 years of service, the installed components are becoming outdated and increasingly difficult to replace in case of failure. To ensure continued reliability and efficiency, a modernisation of the standard is necessary. The primary objective is to optimise the sampling core as well as the voltage and current sensors to extend the measurement ranges. In the optimised, still fully synchronised sampling core, two simultaneously operated sampling voltmeters are used resulting in a reduction of the attainable measurement uncertainty and a higher measurement throughput. New current and voltage sensors with extended measuring ranges up to 100 A and 480 V, respectively, and improved accuracy have already been developed and integrated into the modernised system. This development not only increases operational flexibility, but also supports precise system synchronisation, further improving the accuracy and efficiency of measurement processes. (Alexander.Dubowik@ptb.de)

In Germany, costumer protection related to public charging stations for electric vehicles (EV) is ensured by conformity assessments in laboratories and periodic reverifications on-site. While laboratory tests are feasible, tests in everyday environments in the field are a challenge due to environmental influences, different EV charging characteristics, and specific technical designs of charging stations. Therefore, PTB has developed the Electric Vehicle Charger Inspection System (ELVIS), a stand-alone and autarkic mobile vehicle trailer that fully metrologically characterizes AC and DC charging stations with adjustable test voltages and currents. ELVIS electronically simulates the EV communication, implements the EV energy transmission, and measures the transmitted energy with a power analyzer traced back to PTB standards in an air-conditioned area. AC charging stations can be tested with up to 24 kW and DC charging stations with up to 300 kW of real power. Currently, test options with phantom power of up to 500 kW are being integrated. ELVIS allows metrological testing of charging stations directly on-site for reverification or conformity assessment purposes. (Jannes.Langemann@ptb.de)

4. Magnetic Measurements

PTB develops a novel primary Tesla standard based on hyperpolarized ^{3}He as nuclear magnetic resonance (NMR) probe. Completed activities include the setup of metastability optical pumping, the optimization of magnetic field coils and shielding, the successful detection of up to 50 % hyperpolarization rates in ^{3}He, and finite-element simulations of parameters relevant for the measurement uncertainty. Ongoing work comprises the development and improvement of NMR electronics, software, and data analysis. The project combines PTB efforts in Braunschweig and Berlin to extend the current magnetic field range for the primary Tesla standard covering 10µT to 200mT to lower and higher fields (nT to T range). It also takes advantage of unique PTB infrastructure, like the Berlin magnetically shielded room and the non-magnetic building in Braunschweig, for advanced earth magnetic field cancellation. (Franziska.Weickert@ptb.de)

PTB successfully started a technology transfer project that conveys crucial know-how in the characterization of hard magnetic materials to an SME. Thereby, new calibration capabilities will be made available by a certified calibration laboratory to serve industries active in highly relevant fields like electric vehicles, wind generators, and magnetic sensors, among others. (Joachim.Luedke@ptb.de)

The IEC TC113 "*Nanotechnology standardisation for electrical and electronic products and systems*" has recently published a new standard on traceable spatially resolved magnetic field measurements using the so-called magneto-optical indicator film (MOIF) technique. The standard was developed and drafted within the EMPIR project *qMOIF* coordinated by PTB. It complements the previously developed standard on magnetic force microscopy in view of measurements on a larger length scale (micrometer to centimeter) and thus makes standardized measurements accessible for industrial samples like magnetic scales and electrical steel sheets (Sibylle.Sievers@ptb.de)

Ambient magnetic force microscopy (MFM) can be calibrated to give quantitative spatially resolve magnetic field data, as described in a previously published IEC Technical Specification. In comparison to ambient MFM, MFM in vacuum has better signal to noise ratio due to weaker damping of the oscillations of the MFM cantilever. However, the weaker damping leads also to non-linearities and instabilities rendering the quantitative calibration and the measurement of the sample topography difficult. In cooperation with industry, PTB developed a technique that, first, scans the sample in the presence of an artificially enhanced damping to reliably detect the topography. Then, the magnetic field is detected by measuring the frequency shift of the cantilever which scales linearly with the magnetic signal, employing a phase-locked loop. This approach allows stable and fast vacuum MFM operation and thus enables quantitative spatially resolved field measurements with improved field sensitivity.
(Sibylle.Sievers@ptb.de)

5. High Frequency and Fields

5.1 Electromagnetic Fields and Antenna Measuring Techniques

PTB operates a spherical antenna scanner and offers calibration services for antenna gain and antenna pattern from 1 GHz to 18 GHz, supported by two separate CMC entries. In order to reach substantially higher frequencies, a planar scanner is under development, which in the first stage will allow operation at frequencies up to 110 GHz. This will be achieved by significantly increasing the mechanical stability and improved alignment of the antennas compared to the spherical antenna scanner. To ensure reliable alignment of the mounted antennas, a machine vision system consisting of four cameras combined with a laser tracking system was implemented to determine the positions of the antenna apertures with µm precision. Following the establishment of a detailed uncertainty budget, it is intended to propose extensions to the CMC entries for antenna gain and pattern up to 110 GHz. (Kai.Baaske@ptb.de)

PTB has started work aiming at the characterization of large outdoor emitters. To this end, near-field measurements will be performed using uncrewed aerial vehicles (UAVs). The far-field characteristics will then be calculated from the measured near-field data. This work is funded by the German Science Foundation (Deutsche Forschungsgemeinschaft, DFG) in a project which started in November 2024. (Kai.Baaske@ptb.de)

5.2 High-Frequency Measuring Techniques

PTB submitted CMC extensions for the RF quantity scattering parameters in rectangular waveguides up to 220 GHz as well as some modifications (format changes, small improvements) of measurement uncertainties of existing RF CMC entries. All CMC submissions were accepted. In the next CMC round, it is intended to propose extensions for RF power in rectangular waveguides up to 220 GHz, RF scattering parameters in coaxial lines up to at least 150 GHz, and potentially RF scattering parameters in rectangular waveguides up to 330 GHz. (Karsten.Kuhlmann@ptb.de)

In collaboration with an industry partner, the traceability concept for on-wafer S-parameter measurements developed at PTB was successfully applied to a commercial, customised calibration substrate. A comprehensive uncertainty budget was determined for this alumina substrate, including instrumentation error, connector repeatability, and calibration standard uncertainties. Calibration certificates, enabling the correction of on-wafer S-parameter measurements with commonly used calibrations in industry, were issued for the first time worldwide. (Uwe.Arz@ptb.de)

In an international interlaboratory measurement campaign within the joint research project TEMMT involving five European NMIs, PTB participated in an extensive comparison of measurements of dielectric material properties between 2 GHz and 1 THz using both vector network analyzer (VNA)-based and optics-based methods, employing seven types of commonly used dielectric materials. This is the first time that an interlaboratory measurement comparison of these material properties has been conducted over nearly three decades of frequency and involving such a range of techniques. (Uwe.Arz@ptb.de)

The joint research project “On-wafer microwave metrology for future industrial applications” (OnMicro) within the European Partnership on Metrology Programme (EPM), has started successfully. The major goals of OnMicro include developing calibration substrates for industrial semiconductor technologies (BiCMOS/GaN) up to at least 110 GHz, establishing reliable and accurate on-wafer characterisation techniques for downscaled millimetre-wave and terahertz transistors, and the development of accurate methods for the characterisation of semiconductor materials, thin-films and novel 2D materials. (Gia.Phung@ptb.de)

The joint research project “RF key quantities for 6G development” within the EPM has started in May 2024, coordinated by PTB. The objectives of this project include the extension of the frequency range of PTB´s calibration service for the time response of high-frequency electronic devices such as sampling oscilloscopes and photodiodes. By enabling the measurement system to support 0.8 mm coaxial lines, the frequency range can be extended from 110 GHz to 145 GHz. (Heiko.Füser@ptb.de, Frauke.Gellersen@ptb.de)

Metrological evaluation of broadband modulated signals used in digital communications at high frequencies demands a stringent calibration of the measurement devices. At PTB a traceable full waveform calibration based on an electrooptical sampling (EOS) system is being developed. The analysis and numerical efficiency of calibration algorithms for different instruments (sampling oscilloscope, real-time oscilloscope) is currently being investigated in the Euramet project “Support for standardisation of sample-by-sample waveform uncertainty computation”, which is coordinated by PTB. The project aims at a unified European contribution to the IEC standardization process of sample-by-sample waveform uncertainty computation by implementing and distributing harmonized computational models and data processing routines for various measurement scenarios. (Nora.Meyne@ptb.de, Heiko.Fueser@ptb.de)

6. Digitalization

DKD (German Calibration Service) working groups focusing on the DCC (Digital Calibration Certificate) for DC, low frequency and RF quantities were established and have already held their kick-off meetings. Their members participate regularly in the cross-sectional DKD meetings on the DCC, fostering interoperability and actively working on improvements. It is anticipated to have a common format for tables and an option to express the measurands in the DCC soon. For the DC and low frequency quantities, potential refType definitions have been defined and are currently implemented in the DKD Metrology refType Database. The DKD working group focusing on the DCC for RF quantities plans to work on a good practice example and a guide document. (Rolf.Judaschke@ptb.de, Frauke.Gellersen@ptb.de)