European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-r03**
Version: 1.0

Title: Traceability for AC voltage at frequencies up to 100 MHz

Abstract

During recent years the performance of wideband measuring equipment used in calibration laboratories and industry (such as wideband AC voltage meters and sources) has been considerably improved. The bandwidth of novel wideband AC voltage meters and sources was recently extended to 50 MHz and these instruments play a crucial role in transferring wideband AC voltage traceability from primary level to calibration laboratories and industry. Due to the lack of efforts to continuously develop calibration services in this area the supporting metrology lags behind the market. In order to meet the requirements for the calibration of novel wideband instrumentation (such as wideband AC voltage meters and sources or high-speed digitizers) the Radio Frequency to Direct Current (RF-DC) standards, measurement methods and setups need to be improved.

Keywords

AC voltage, RF-DC, power sensors, thermal voltage converters, matched system, unmatched system, transmission line

Background to the Metrological Challenges

The increasing requirements for measurement of AC voltage in frequency bandwidth over 1 MHz are coming from various areas of research, industry and society and there has been insufficient research on the methods used to measure AC voltage at frequencies between 1 MHz and 100 MHz. This has led to poor traceability and thus none of the published CMCs are covering the precision needed for many applications in this area. Currently, there are only three European NMIs with published CMCs in the category RF-DC difference based on RF-DC standards fully covering the bandwidth 1 MHz to 100 MHz and three others with published CMCs in this category with reduced bandwidth. Uncertainties provided by these CMCs are insufficient and cannot fulfil the requirements for calibration of novel wideband instrumentation. A few European NMIs also published CMCs for RF voltage from 1 MHz up to 100 MHz based on microwave power realisations but none of these CMCs have sufficient accuracy to verify novel wideband instrumentation.

The measurement of harmonics as part of power quality analysis in novel smart electrical grids is continuously expanding to even higher frequencies. Recently, a traceable power quality measurement setup was developed at frequencies up to 1 MHz in scope of EMPIR project 15RPT04 TracePQM and substantial research is being undertaken with EMPIR project 20FUN07 SuperQuant to base AC voltage metrology on fundamental constants by using quantum standards which are still experimental in bandwidth over 1 MHz and will need to be verified and validated by using other measurement methods with sufficiently low uncertainties. The improved RF-DC measurement methods up to 100 MHz will support traceability of research projects dealing with increasing bandwidth of AC voltage measurement such as development of power quality wideband measurement methods or development of wideband quantum standards.

To fulfil the requirements on calibration of wideband instrumentation the voltage range needs to be extended from the voltage level of the primary realisation to the range of 1 mV Root Mean Square (RMS) to 7 V RMS by using step-down and step-up methods. Because the bandwidth of the wideband instruments extends to low frequencies in a matched system, the new measurement set up based on novel RF-DC standards and power sensors must be designed to accommodate frequencies well below 1 MHz as well as extending up to 100 MHz.

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Moreover, further research needs to be undertaken to improve the knowledge of RF-DC measurement in order to further decrease the total measurement uncertainties. With increasing frequency, the transmission line effects (such as reflections, standing waves) are of importance especially if the impedance of the whole measurement system is not exactly matched as well as connection of the setup (such as grounding and guarding techniques, quality of connectors and cables), which significantly contribute to the uncertainty budget. A suitable theory of transmission line effects in an unmatched RF-DC based measurement setup has not yet been properly elaborated. To quantify the mismatch influence, coordinated parameter studies over a wide area of hardware properties need to be carried out. The outcome should be compared to reference measurements undertaken by the experienced NMIs and used in the drafting of guidelines or development of open software.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the development of traceable regional/national measurement capabilities in the RF-DC field up to 100 MHz.

The specific objectives are

1. To create and disseminate knowledge on the suitable and most commonly used standards, instrumentation and measurement methods on the metrology of AC voltage in the frequency range 1 MHz to 100 MHz. In addition, a review of existing measurement methods, standards, hardware and software should be undertaken in order to collate the fragmented knowledge.
2. To develop novel RF-DC standards including thermal and calorimetric converters at input voltages from 1 to 5 V RMS and frequencies up to 100 MHz with target uncertainty better than 10 uV/V at 1 MHz and 500 uV/V at 100 MHz.
3. To develop a new measurement setup based on the novel RF-DC standards and power sensors in the voltage range 1 mV to 7 V RMS and frequencies up to 100 MHz. The new setup will be designed by the gathered improved knowledge based on conducted investigations of the connections, transmission line effects, hardware performance and uncertainty analysis. To operate the setup an open software tool will be developed and tested to control the hardware and evaluate the results.
4. To verify, validate and provide at least two new working setups based on the novel RF-DC standards and power sensors targeting the voltage range and uncertainties needed for verification of novel wideband instrumentation. To prepare a guide for the new measurement setup based on the novel RF-DC standards and power sensors in order to transfer the expertise to developing NMIs.
5. To facilitate the take up and long-term operation of the capabilities, technology and measurement infrastructure for AC voltage measurements developed in the project, by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), and end users (e.g. industry, instrument manufacturers, regulators). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, e.g. via EURAMET TC-EM and EMN for Smart Electricity Grids (SEG), to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,
- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMPIR projects 15RPT04 TracePQM and 20FUN07 SuperQuant and how their proposal will build on those.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.7 M€ and has defined an upper limit of 0.9 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge initially to the accredited laboratory sector and to instrument manufacturers and ultimately to the wider metrology community.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.