EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s02**
Version: 1.0

Title: Traceability for electrical measurements at millimetre-wave and terahertz frequencies for communications and electronics technologies

Abstract

This SRT intends to establish SI traceability for a range of electrical measurement quantities at millimetre-wave and terahertz frequencies. This traceability is needed by many emerging applications, exploiting communications and electronics technologies such as 5G, Internet of Things (IoT), Connected Autonomous Vehicles (CAV), space-borne radiometers for Earth remote sensing, security imaging, etc. Proposals should concentrate on S-parameters (for loss and phase change), power and material measurements (complex permittivity) and should enable European NMIs to provide SI traceability for these parameters at very high frequencies thus benefiting directly the communications and electronics industries.

Keywords

Traceability, millimetre-wave, terahertz frequencies, electronics technologies

Background to the Metrological Challenges

From the end-user perspective, applications are already in place (or are being developed) that rely heavily on using the frequency range above 100 GHz (i.e. millimetre-wave and terahertz frequencies). In the communications sector, the use of these higher frequencies is particularly attractive because it enables much wider bandwidths to be used, for high speed, high density signal propagation. In addition, signal propagation is moved away from the spectrally congested regions at lower frequencies (i.e. to avoid the so-called 'spectrum crunch' dilemma). Several 'propagation windows' exist in the millimetre-wave and terahertz frequency range that can be exploited for this and many other applications.

The development of devices and systems operating at frequencies above 100 GHz is hampered by the lack of traceability for electrical measurements. For example, despite the fact that power meters working up to 1 THz are already commercially available, there is no SI traceability to benchmark these measurements which can be accessed by industrial and other end-users. In addition, commercially available frequency extender heads and calibration kits for vector network analysers (VNAs) enable these systems to measure S-parameters to 1.5 THz. These VNA systems can also be adapted to measure materials properties (e.g. complex permittivity) using commercially available materials characterisation kits at all frequencies up to 1.1 THz. However, again there is no SI traceability for this measurement capability.

Currently, traceability in the 50 GHz to 1.5 THz frequency range is poorly served by the global NMI community. For power measurement and materials measurement existing traceability services extend only to 110 GHz and this is only available in selected NMIs. Some S-parameter measurement capability was put in place by some European NMIs, at some selected frequencies, in the EURAMET EMRP SIB62 project but these services were essentially proof-of-concept capabilities and not suitable as Calibration and Measurement Capability (CMC) entries in the BIPM key comparison database. New metrology, at the NMI level, is thus urgently needed to address this lack of traceability so that the capabilities of the mentioned high frequency measurement systems – for S-parameter, power and material measurements – can be fully exploited.

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.

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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

The JRP shall focus on the traceable measurement and characterisation of electrical measurement quantities at millimetre-wave and terahertz regions of the electromagnetic spectrum.

The specific objectives are

1. To develop traceability and verification techniques for S-parameters (that measure the loss and phase change for transmitted and reflected signals) by implementing the techniques in coaxial lines fitted with the new E-band connector (to 90 GHz); on-wafer to 1.1 THz; and, in waveguide to 1.5 THz. At least two waveguide bands should be covered: one in the millimetre-wave region (between 50 GHz and 300 GHz) and one in the submillimetre-wave (i.e. terahertz) region (between 300 GHz and 1.5 THz).
2. To develop traceability of power measurements in waveguide to 750 GHz. At least two waveguide bands should be covered as described in Objective 1.
3. To develop traceability to measure material properties such as complex permittivity and loss tangent to 750 GHz. At least two waveguide bands should be covered as described in Objective 1.
4. To facilitate the take up of the technology and measurement infrastructure developed in the project by other NMIs with the view of forming a coordinated network of NMIs that provide a comprehensive measurement capability as well as by the measurement supply chain (research institutes, calibration laboratories), standards developing organisations (such as e.g. IEEE P287, IEEE 1785) and end users (manufacturers of telecom equipment, measuring instruments, absorber materials).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP SIB62 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

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

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 JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the communication and electronics sector.

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 EMPIR 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

Time-scale

The project should be of up to 3 years duration.