

## **Title: RF key quantities for 6G development**

### **Abstract**

The next generation (6G) of wireless communication systems is currently under development and is expected to deploy at the beginning of the next decade. 6G aims at spectacular specifications to support and enable modern, digital and highly connected applications. The proposed research wants to extend the metrological support for RF key quantities - as RF power, S-parameters and wave form quantities - in line-based systems with connectorised interfaces to meet the challenges being set by the 6G specifications and provide underpinning support to the industries involved in the current R&D efforts.

### **Keywords**

6G wireless technology, RF key quantities, power, S-parameters, waveform, high speed digital

### **Background to the Metrological Challenges**

6G roll-out is anticipated for the end of the decade. R&D activities towards concrete solutions are gaining traction. Manufacturers of measuring devices and components are positioning themselves as 6G solution providers. Underpinning support from radiofrequency (RF) metrology in the form of new measurement techniques and extended traceability for RF key quantities is crucial.

The main 6G objectives and challenges can be summarised as follows: Data rates potentially up to 1 Tbps with ultra-low latency (down to  $\mu\text{s}$ ) and high reliability (for mission critical applications, e.g. autonomous driving). The high data rates require spectrum availability from a few GHz to several hundred GHz. Energy and cost efficiency (low power consumption, low heat emission, low hardware and infrastructure costs) are anticipated as well. High compactness, miniaturisation and integration will support all these desired features. The need is strongly driven by high-speed digital applications, i.e. measurements in the time domain. Measurement capabilities in the frequency domain are also needed to transfer traceability between different line-based systems.

The official operating frequencies of 6G have not yet been fixed, but current research efforts lead up to 220 GHz or even 250 GHz. Industries supporting these developments are looking for traceability up to these frequencies. Traceability above 110 GHz is only available for some systems based on metallic waveguides, but these are banded systems with a frequency limit at the low end.

The upper frequency limit of traceability for existing wave guide RF power primary systems is 170 GHz. The upper frequency limit for existing power sensor transfer standards (microcalorimeter capable) is limited to prototypes, operating up to 170 GHz.

Coaxial line systems are not specified to operate at their theoretical upper limit (specified by the size of the transmission line). The upper frequency limit of coaxial connectors is currently limited to 110 GHz (1 mm connector). Today's S-parameters phase standards are difficult to operate and cause high costs, while traceability is elaborate and currently limited to two NMIs worldwide, operating electro-optical wave form standards. Existing attenuation standards are high maintenance, costly in operation, low frequency devices and for higher frequencies they employ frequency-mixing. Matching and stability conditions become a concern with increasing frequencies.

Currently, the transfer characteristics and intrinsic time responses of high-speed electronic devices can be traceably calibrated up to a frequency limit of 110 GHz. Using a purely electro-optically operated voltage pulse standard, the frequency restriction results from the 1 mm coaxial connection of the device under test.

## 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 JRP shall focus on extending the metrology for RF key quantities in line-based connectorised systems in frequency and in time domain to support 6G wireless developments.

The specific objectives are

1. To develop waveguide based primary standards (microcalorimeter) for RF power measurements up to 220 GHz. To develop a microcalorimeter capable transfer standard (for the traceability transfer to secondary standards) up to 220 GHz. To evaluate novel concepts for a transfer standard, which could operate to even higher frequencies (e.g. 330 GHz).
2. To extend frequency range of broadband coaxial connectors by pushing up standardised frequency limits of existing coaxial line systems and establish traceability for new coaxial sub-mm connectors up to 220 GHz. To develop phase standards based on novel concepts, as e.g. a calculable diode, for non-linear/large signal S-parameter measurements to at least 67 GHz. To develop and validate novel linearity characterisation methods for different vector network analyser (VNA) setups up to 220 GHz. To develop a novel VNA based primary attenuation standard up to 220 GHz.
3. To establish traceable calibration procedures for electrical waveform parameters up to a 3 dB-bandwidth of at least 145 GHz. To demonstrate the characterisation of a high-speed photodetector module suitable for datacom and telecom applications.
4. To engage with industry to ensure that the specifications of measurement and test systems required by 6G developers can be met by device and component manufacturers. To directly involve industry in the project as component and system suppliers to allow for maximum uptake. To update EURAMET calibration guides.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrument manufacturers), standards developing organisations (ISO/IEC/ETSI), and end users (e.g. telecommunication network infrastructure, manufacturers of components and system suppliers).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

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 projects 18SIB09 TEMMT and SIB62 HFCircuits, and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % 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 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,

- 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 to the telecommunications 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 the 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.

### **Time-scale**

The project should be of up to 3 years duration.