EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT-i10**
Version: 1.0

Title: Metrology for the next generation of modulated radio frequency signals

Abstract

With the increasing complexity of communication systems and protocols, the exact knowledge of digital signal properties is key for system design and operation. New developments are accompanied by highly specialised measurement equipment such as communication and vector signal analysers, but a reliable traceability chain for these is currently missing. Proposals in response to this SRT should address these issues by developing validated methods and establishing traceability chains for the next generation of modulated radio frequency signals.

Keywords

Waveform metrology, digital-signal properties, mixed-signal analysis, D-parameters, analog-to-digital converters, vector-signal analysers, electric pulse-generators, field-strength,

Background to the Metrological Challenges

As the complexity of systems and protocols in ultra-high speed and high density communications increases, so exact knowledge of digital signal properties, quality factors and adherence to spectral limits with known measurement uncertainty becomes crucial. Furthermore, for new technologies to be accepted, their conformity with safety limits such as IEEE 802.15, must be established.

Digital sampling oscilloscopes (DSO) are used to calibrate electromagnetic compatibility (EMC) pulse generators, ultra-wideband communications (UWB) pulse generators and radar pulse. Calibration algorithms have been developed to support the use of digital real-time oscilloscopes (DRTO) needed for these tasks, however without the proper characterisation of the oscilloscope, the signal analyser measurements cannot be treated as reliable. In addition, although dedicated measurement equipment for digitally modulated radiated signals is currently available, calibration capabilities only exist for averaged (root mean square) field strengths, which is not appropriate in environments with a multitude of different signals, and there are issues when establishing a traceability chain for vector signal generators multi-sine test signals and vector signal analysers.

The frequency resolution that can be achieved when transferring traceability from the electro-optic primary standard is coarse when compared with the acquisition epoch, and hence frequency resolution, of a DRTO. Therefore, DSO calibration to other DSOs must be transferred using electrical pulse generators and finally to DRTOs, which can be used to measure Error-Vector Magnitude (EVM). While calibration seems feasible for simple modulation schemes, the traceable calibration of complex communication protocols e.g. Universal Mobile Telecommunications Service (UMTS), Long-Term Evolution (LTE) and 5G poses more challenges. For some of the complex protocols, code and segments that could be used for calibration purposes are specified in the 3GPP/ETSI standard documents, and work on specifying waveforms for EVM measurements has started. However, all of the relevant contributions to the measurement uncertainty of the calibration of VSAs and VSGs including those arising from hardware impairments must be identified.

Recent advances in software-defined radio technology have pushed mixed-signal circuits, which are needed to fully access the characteristics of fast analogue-to-digital converters, to operate at higher frequencies. This is particularly important for high-efficiency amplifier designs which require several digitally pre-distorted inputs in order to achieve their required performance. Digital pre-distortion of amplifiers increases the available bandwidth in the baseband significantly but needs rigorous characterisation of linearity, frequency response and noise of the receiver stage. Therefore the next generation of mixed signal components will require robust definitions and test strategies so that they can be integrated into the design process.

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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 the traceable measurement and characterisation of modulated radio frequency signals.

The specific objectives are

1. To develop validated methods using real-time-oscilloscopes for the characterisation of (i) electric pulse generators used for the calibration of EMC test equipment, (ii) pulse-modulated radio-frequency sources used for UWB and (iii) automotive radars. This should include the implementation and evaluation of interpolation techniques and regularisation filtering.
2. To establish a traceability chain for the calibration of vector signal and communication analysers. This should be based on real-time oscilloscopes and signal analysers and include an analysis of the uncertainty from amplitude and phase modulation properties to more complex digital modulation metrics, in particular EVM, as well as appropriate quality metrics for LTE and 5G.
3. To develop traceable and validated methods for the characterisation of mixed signal systems and fast analogue-to-digital converters. This should include the metrological evaluation and optimisation of novel measurement methods, in particular D-parameter characterisation.
4. To validate the traceability of digital-signal quality metrics and field-strength of radiated signals in existing communication formats i.e. 5G, LTE, UMTS and constellation metrology in orthogonal frequency division multiple access systems. In addition to assess the measurement uncertainty for such communication formats including the effect of hardware and channel influence on digital signal properties.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project, in particular an infrastructure enabling calibration with uncertainty better than 1 % for selected estimated parameters, by the measurement supply chain e.g. calibration laboratories, standards developing organisations e.g. IEEE Modulated Signal Measurement Uncertainty (MSMU) WG, IEEE 802.15 wireless personal area network (WPAN) and ETSI, and end users e.g. the communications industry. This should include the development of draft IEEE and VDE/VDI guidelines.

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 EMRP IND16 Ultrafast, EMRP IND51 MORSE and EMPIR 14IND10 MET5G and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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,

- Transfer knowledge to the communications 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.