Title: RF Measurements for future communications applications

Abstract

The widespread implementation of future communications such as 5th generation (5G) and Connected Autonomous Vehicles (CAVs) presents challenges for the developed technology as electronic radio frequency (RF) components, circuits, subsystems and systems must be characterised and demonstrate good performance in "real world" operating conditions. Nevertheless, NMIs in Europe lack the capacity to carry out the RF measurements necessary to support the communications sector. Proposals addressing this SRT should contribute towards radio frequency electrical metrology to support standardisation in future communications applications by providing measurement capability to assess devices' performance in realistic conditions and promote the take up of the technology.

Keywords

RF measurements, communications high-power amplifier, Field-Programmable Gate Array (FPGA) chips, signal-integrity, power-integrity, passive inter-modulation

Background to the Metrological Challenges

The rollout of the global 5G communications infrastructure is now well under way in several parts of the world and is set to continue during much of this decade as more countries have access to this new global network. This means that the systems developed and characterised in research and development laboratories must operate in the "real world" environments.

From the end-user perspective, applications are already being developed that require improved proposed measurement facilities. High-power transistors (developed using e.g. GaN, SiGe and Complementary metal-oxide-semiconductor (CMOS) technologies), which are used in 5G base stations and mobile handsets are far-removed from the classical impedance-matched linear measurement test set-ups. In addition, electronic circuits developed for use in driver-assisted vehicles operate in a wide range of climatic conditions, and in New Space applications, lead-free soldering may affect other components. Furthermore, coaxial connectors used in communication networks generate intermodulation products that can have a detrimental effect on the overall operation of these communications networks; and Printed Circuit Boards (PCBs) where components are densely packed can either affect or been affected by electromagnetic interference that can cause components to malfunction or to stop working completely. Therefore, additional work is necessary to evaluate the impact of signal-integrity and power-integrity on FPGA chips and electromagnetic interference (EMI) evaluation in real operating conditions, at the input/output interfaces and on chip.

The measurement capability developed in the project EMPIR ADVENT 16ENG06 focused on characterising devices operating at ambient conditions. However, it has been demonstrated that the performance of these devices is affected by changes under realistic environmental conditions and therefore novel methods are needed to assess the performance and to overcome this issue.

The IEC series of standards, which are widely used by the telecommunications industry, underline the need for reliable passive inter-modulation (PIM) measurement systems. However, there are several aspects relating to PIM that are not covered by these standards – e.g. frequency dependence, localisation of PIM, and environmental factors. All these aspects need to be addressed as a next step. Many RF infrastructure use dozens of RF coaxial connections, that were not included in the previous EMRP project, SIB62 'HFCircuits' and their study is required to provide metrology grade connectors.

There are currently no measurement facilities at NMIs in Europe that can provide the necessary measurements as in "real world" operating environments such as harsh environment (e.g. below- and above-ambient temperatures) or non-optimum configurations (e.g. in electronic circuits where neighbouring components are causing substantial signal interference). It is essential that a reliable measurement capability is established within Europe to enable the evaluation and validation of devices in these scenarios and it is necessary for a group of European NMIs to develop and provide these capabilities to European industry.

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 radio frequency electrical metrology to support standardisation in future communications applications

The specific objectives are

1. To characterise active devices (e.g. transistors realised in GaN, SiGe and CMOS technologies) and circuits, particularly high-power amplifiers, under realistic operating conditions (non-50 Ω) at frequencies that include the millimetre-wave bands (e.g. to at least 200 GHz). The characterisation should include the linearity response of the devices and encompass multi-physics methods, mixed-domain measurements (combining digital and analogue domains), new probing techniques and assessments of antennas integrated on-chip.
2. To evaluate the impact of signal-integrity and power-integrity on Field-Programmable Gate Array (FPGA) chips, including the quantification of effects caused by electromagnetic interference (EMI) on high-speed digital circuits during operation. This should include i) the design of rules for the location of components (e.g. integrated circuits) on chip and on Printed Circuit Boards (PCBs) based on *in-situ* assessments of performance; and ii) the development of methods to validate test data and assess parasitic effects due to components operating simultaneously in close proximity on chip.
3. To assess the system operation performance in real world and harsh environments (e.g. below- and above-ambient temperatures, different climate conditions and changing levels of relative humidity). This should include the development of methods for assessing the performance of the electronic components and circuits in diverse operating applications (e.g. Connected and Autonomous Vehicles and New Space).
4. To develop and validate novel measurement methods to evaluate the passive inter-modulation (PIM) of RF electrical signals used in communication systems. These methods should be suited for industry-grade connectors (e.g. SMA, 7/16 and type-N connectors, and, newer variants including the 4.3/10 connector).
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, calibration laboratories), standards developing organisations (IEEE) and end users (in the fields of telecommunications, automotive, defence, space and security).

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 SIB62 HFCircuits and EMPIR 16ENG06 ADVENT projects 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 across all selected projects in this TP.

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 electronics and communication sectors.

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.