EMPIR Call 2014 – Industry and Research Potential

Selected Research Topic number: **SRT-i17**
Version: 1.0

Title: Microwave measurements for planar circuits and components

Abstract

Although on-wafer HF measurements already have an economic impact on chip fabrication costs, industrial assurance and traceability have not yet been established. Industry needs methods to perform reliable on-wafer scattering-parameter measurements up to sub-mm wavelengths. Boundary conditions of the setup and parasitic modes are often not sufficiently considered, leading to inconsistent results. Utilising modern advanced vector network analysers together with state-of-the-art numerical simulation techniques to fully capture all relevant effects will enable industry to characterise components and devices in high-speed and microwave applications with known measurement uncertainties.

Keywords

On-wafer microwave measurements; vector network analysis; planar circuits and components; microwave, millimetre-wave and sub-millimetre-wave frequencies; calibration substrates; parasitic modes; interconnect characterisation; microwave probe crosstalk compensation; surface roughness; RF nanotechnology and nanodevices

Background to the Metrological Challenges

Technology roadmaps foresee the further development of electronics and nanoelectronics as the key enabling technology for the whole of European industry [1-4]. Emerging RF, mm-wave and sub-THz consumer applications include 77/120 GHz automotive radars, mm-wave imaging and sensing, 60 GHz wireless networks, 400 Gbit/s fibre optics data communication systems, high-performance RF wireless communication systems as well as two-way satellite communication systems. Other areas with mm-wave and sub-THz applications are health science, materials science, genetic screening, security and industrial automation.

These extraordinary advances in technology require new high-speed microwave signal and waveform measurements. Due to the bandwidth limitations and prohibitive costs of coaxial and rectangular waveguides at higher frequencies the only feasible alternative are on-wafer measurements in planar transmission lines. Because the speed of the devices is often linked to size, it is important to develop this on-wafer metrology at both conventional integrated-circuit and nanoscale dimensions and at both conventional and high impedance levels.

Microwave measurements performed on semiconductor wafers occur at a critical stage in prototyping prior to large production runs and final packaging. Methods of calibration for S-parameter measurements vary considerably from organisation to organisation. While it is quite common in industry to use commercially available calibration substrates (so-called impedance standard substrates), the associated calibration methods suffer from parasitic effects in the lumped element standards at higher frequencies, typically above 20 GHz. Some organisations make use of custom-made transmission-line standards and achieve better calibrations at higher frequencies.

Currently within the on-wafer community there is little agreement or data available as to a ‘quality’ calibration, no rigorous quantities exist for measurement boundaries. Only recently have uncertainty calculations been developed, but still no traceability exists. A typical conformance check at present is to observe an open circuit device following calibration and ensure it falls within 0.1 dB of the expected 0 dB level. Any structure within the measurement is attributed to parasitic elements and generally ignored.

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 proposal.

The JRP shall focus on the traceable measurement and characterisation of integrated planar circuits and components from radio-frequency (RF) to sub-mm frequencies.

The specific objectives are

1. To develop calibration substrates and algorithms for planar scattering parameter measurements up to at least 325 GHz, including the characterisation of calibration standards built in selected substrate materials through dimensional measurements, wideband substrate permittivity extraction and numerical simulation. Guidelines should be developed on the suppression of excitation of unwanted parasitic modes.
2. To establish traceability of planar scattering parameter measurements on reference calibrations. The aim should be to provide the lowest possible uncertainties for scattering parameter measurements of devices embedded on the same wafer and the uncertainties should be quantified. Candidates for these calibrations, such as airline-like interconnects in membrane technology and substrates such as GaAs which allows comparisons to electro-optic waveform metrology, should be evaluated.
3. To transfer uncertainties to the calibration standards based on conventional technology that are used in industry, in order to address the difficulty of moving between different substrate materials and different planar waveguide types. Residual errors of the calibration to be quantified with regard to the selected calibration algorithms and the influences of probe geometry and technology.
4. To improve planar transmission lines models to account for surface roughness and radiation, which are of fundamental importance to the microwave design and circuit community, but also to enable the development of reliable uncertainty budgets for planar S-parameter measurements.
5. To develop suitable calibration standards and methods for measurements of RF nanodevices. These should address issues such as the impedance mismatch problem for calibrated S-parameter measurements of nanodevices and also the challenge of probing at nanoscale dimensions.
6. To engage with manufacturers of planar microwave circuits and components to facilitate the take up of the technology and measurement infrastructure developed by the project.

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.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any 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 deviation from this must be justified.

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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the electrical and electronics sector.

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

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.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] European Nanoelectronic Research Council. *Multi Annual Strategic Programme*, 2010.
Online: http://www.eniac.eu/web/downloads/documents/masp2010.pdf

[2] European Commission. *Vision 2020 - Nanoelectronics at the Centre of Change*. 2004,
ISBN 92-894-7804-7, online: ftp://ftp.cordis.europa.eu/pub/nmp/docs/nanoelectronics_platform.pdf

[3] *International Technology Roadmap for Semiconductors* (2011 edition).
Online: http://www. itrs.net/Links/2009ITRS/Home2009.htm

[4] *"Big" Problems in Electromagnetics.* CCEM Strategic Planning Document. Revision 1.2, May 2011.
Online: http://www.bipm.org/utils/common/pdf/CCEM-WGSP-2011.pdf