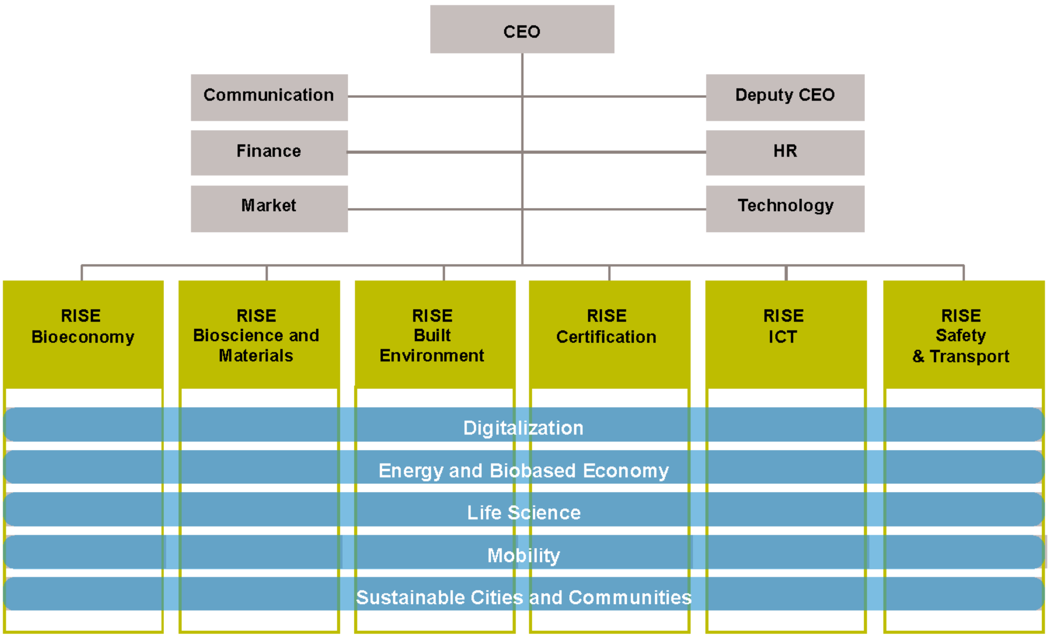
Contact person
Karl-Erik Rydler
Measurement Science and Technology
+46 10 516 54 01
karl-erik.rydler@ri.se

Report from RISE Research Institutes of Sweden within the field of Electrical Metrology

Organisation

During 2016 SP Technical Research Institute of Sweden AB and two other research institutes Swedish ICT and Innventia have merged to form RISE Research Institutes of Sweden. From 1 Jan 2017 we are working under this name, www.ri.se. The reason for the merger is to create a unified institute sector and become an even stronger innovation partner for businesses and society. RISE is organized in six Divisions and, so far, five horizontal Business and Innovation Areas. RISE operates from some 35 sites all over Sweden plus a few abroad. The new headquarter will be located in Gothenburg. RISE has a staff of about 2200 and a turnover of 300 MEUR. The Swedish state is the sole owner of RISE.



Some of the board of directors of RISE are: CEO Pia Sandvik, Deputy CEO Olof Sandén, CBDO Johan Rune Nielsen and CTO Margaret McNamee. The activities as a NMI will continue to be coordinated by the Department for Measurement Science and Technology which is now part of the Safety and Transport Division. The Department of Measurement Science and Technology also holds most of the staff working in the field of metrology or quality assured measurements, about 110 employees. Professor Jan Johansson is the NMI director.

Technical news since last CCEM meeting in 2015

Subfield DC and Quantum metrology

SP has participated in three EMRP projects which finished in 2016: AIM QuTE, Q-WAVE and GraphOhm.

In AIM-QuTE, a two terminal impedance bridge based on two programmable Josephson voltage standards (PJVS) was developed. The bridge was successfully used to demonstrate capacitance measurements with ratios 1:1 and 1:10 in the frequency range from 25 Hz to 2 kHz. An on-site comparison was performed between the SP bridge and the PJVS bridge developed at PTB. The results were reported at the CPEM 2016 conference in Ottawa. [D1,D2]

In Q-WAVE, a highly stable, low distortion analogue filter was developed and used to generate spectrally pure waveforms from a PJVS programmed with a Delta-Sigma modulated waveform. [D3] The generated waveforms had very low distortion, but the amplitude stability was not as good as expected. Further investigations will be performed to improve the system.

In GraphOhm, we fabricated several QHR samples, both for DC and AC resistance measurements. We made an internal comparison between traditional GaAs samples and the new graphene samples, and found that we could lower the uncertainty by almost a factor of 3 with graphene samples. We also demonstrated the method for adjusting carrier density of graphene based on corona discharge as a practical and effective method for QHR calibration. The results were presented at the CPEM 2016 conference in Ottawa. [D4]

We are continuing our research on graphene in collaboration with Chalmers University of Technology. [D5] A new gating method based on a combination of chemical and electrostatic methods is being developed, which looks very useful for QHR metrology applications.

SP participates in an EMPIR project, QuADC which started in 2016. SP’s work in this project is to develop voltage dividers for direct scaling of Josephson based voltage waveforms up to 1 kV and 100 kHz. As part of this work, we have developed a buffer amplifier which will be used together with the voltage dividers.

SP has acquired a 10 V programmable Josephson array which will replace our previous SIS arrays for DC voltage realisation. With the new array we plan to build automated systems for Zener reference calibrations and voltmeter linearity calibrations. The new array will also be used for AC applications such as AC-DC difference and impedance measurements.

References:

[D1] G. Eklund, T. Bergsten and K. E. Rydler, "A low frequency Josephson impedance bridge," 2016 Conference on Precision Electromagnetic Measurements (CPEM 2016), Ottawa, ON, 2016, pp. 1-2.
doi: 10.1109/CPEM.2016.7540509

[D2] G. Eklund, T. Bergsten, T. Hagen, L. Palafox and R. Behr, "A comparison of the Josephson impedance bridges of PTB and SP," *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016)*, Ottawa, ON, 2016, pp. 1-2.
doi: 10.1109/CPEM.2016.7540584

[D3] T. Bergsten, G. Eklund, V. Tarasso and K. E. Rydler, "An Active Filter for Delta-Sigma-Modulated Josephson Waveforms," in *IEEE Transactions on Instrumentation and Measurement*, vol. 64, no. 6, pp. 1559-1563, June 2015.
doi: 10.1109/TIM.2015.2418454

[D4] T. Bergsten and G. Eklund, "Comparison between GaAs and graphene QHR standards for resistance realisation at SP," *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016)*, Ottawa, ON, 2016, pp. 1-2. doi: 10.1109/CPEM.2016.7540514

[D5] H. He *et al*., "Fabrication of graphene quantum hall resistance standard in a cryogen-table-top system," *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016)*, Ottawa, ON, 2016, pp. 1-2. doi: 10.1109/CPEM.2016.7540516

Subfield Power and Energy

Power and energy

Work on our high frequency power reference system has progressed and we have made improvements to reduce uncertainties by calibrating linearity of digitizers using a thermal transfer standard. A new uncertainty budget has been developed with improvements by a factor of 1.5 to 5. The improved reference system was presented at International Congress of Metrology 2015 in Paris and at CPEM 2016 in Ottawa.

References:

[P1] T. Bergsten, V. Tarasso and K. E. Rydler, "An electrical power reference system Up to 1 MHz," *2016 Conference on Precision Electromagnetic Measu*rements *(CPEM 2016)*, Ottawa, ON, 2016, pp. 1-2. doi: 10.1109/CPEM.2016.7540733

High voltage and current

SP participates in ENG61 Future Grid that commenced in June 2014 and is leading a work package for development of a fibre optical current sensor (FOCS) using the Faraday Effect. The project is in its final stage (May 2017) and three different FOCS systems have been built and studied. The target uncertainty for the FOCS is 100 µA/A for 1 – 10 kA, but the principle has no indication for an upper current limit.

SP is coordinating an EMPIR project 14IND08 Elpow, which started June 2015. This project is to provide metrological background for UHV dielectric testing to extend the voltage range of traceable lighting impulse testing to the ultra-high level of approximately 3500 kV. Traceability is developed for measurements of fast transient voltages, such as those used in puncture testing on insulators, together with calibration circuits for impulse current measuring systems. Services are developed for the need to prove losses, by producing facilities for the loss measurement of large power transformers, reactors and power capacitors and AC cables. Furthermore, a new measurement system is developed for the determination of ac resistance of low loss high voltage ground cables. A measurement system for direct measurement of HVDC converter station loss will be developed, where the loss is determined by simultaneous measurement of AC and DC power.

SP is coordinating a pre-normative EMPIR project 15NRM02 UHV started in May 2016. In this project metrology is developed for calibration of doses in medical X-ray machines. It is also to provide traceability for measurements of 10 ns rise time for Very Fast Transients present in e.g. GIS systems and provide metrology for transmitted over-voltages in voltage transformers. A method for ultrasensitive partial discharge (PD) measurements will be developed, with the target for new CMC entries of PD of 0.1 pC. New PD measurement methods are developed for measurements under d.c. stress.

In the ENG07 HVDC project two 1000 kV dividers where designed and built [H1][H2]. One 1000 kV wideband HVDC reference divider and one 1000 kV reference divider for the lab of SP where calibrated and intercompared in a final test at Aalto University in Espoo [H3][H4]. Both dividers reached an unprecedented accuracy, which surpassed the project measurement uncertainty target by a factor of 2 – 5, initially giving a conservative CMC-entry of 50 μV/V expanded measurement uncertainty. Uncertainty calculation shows that 10 μV/V is achievable [H6][H7], and a new CMC entry of 20 μV/V was accepted in April 2016. The long-time stability in calibration of the resistance values of the SP divider HV modules is better than 1 μΩ/Ω, which has been obtained using the Hamon transfer method.

The modular divider has been used for several traceable calibrations of HVDC measuring systems up to 1 MV in customer's laboratories and shown a very high stability and robustness. On-site measurements confirms that the wide bandwidth also give a capability of measuring switching impulse to a full 1000 kV. The switching impulse capability of the HVDC divider has been further developed for measurements of composite wave shapes, using a transient recorder on the shield stack for switching impulse measurements combined with d.c. measurements on the precision stack.

[H1] J. Hällström, A. Bergman, S. Dedeoğlu, A P. Elg, E. Houtzager4, J.V. Klüss, T. Lehtonen1, W. Lucas, A. Merev, J. Meisner, E. P. Suomalainen and C. Weber "Design and performance of a wideband 1000 kV HVDC modular reference divider." ISH2013.

[H2] Alf-Peter Elg, Anders Bergman, Jari Hällström, Ilkka Iisakka and Tapio Lehtonen, "Optimization of the frequency response of a 1000 kV shielded HVDC reference divider", ISH2013.

[H3] Jari Hällström, Anders Bergman, Senior Member, IEEE, Serkan Dedeoğlu, Alf-Peter Elg, Ernest Houtzager, Senior Member, IEEE, Joni Klüss, Tapio Lehtonen, Wolfgang Lucas, Johann Meisner, Ahmet Merev, Matthias Schmidt, Esa Pekka Suomalainen, Tatu Nieminen, and Christian Weber "Performance of a modular wideband HVDC reference divider for voltages up to 1000 kV", Dig. Conf. Prec. Electrom. Meas., CPEM 2014, Rio de Janeiro, Brazil, pp 782-783, July 2012.

[H4] Alf-Peter Elg, Anders Bergman, Jari Hällström, M Kharezy and T. Nieminen "Traceability and characterization of a 1000 kV HVDC reference divider", Dig. Conf. Prec. Electrom. Meas., CPEM 2014, Rio de Janeiro, Brazil, pp 780-781, July 2012.

[H5] A. Bergman, S. Bergman, C. Hoffmann, E. Paulus and A-P. Elg, "Traceable measurement of dielectric dissipation factor at Very Low Frequency", ISH2013

[H6] Alf-Peter Elg, Anders Bergman, Jari Hällström " Long Term Stability of Two 1000 kV Voltage Dividers, ISH 2015.

[H7] A-P. Elg, J Meisner "1MV-HVDC Teiler", PTB Seminar no 288 , Feb 2015

Subfield RF and MW

Guided waves

The high frequency laboratory at SP participates in the project 14IND10 MET5G Metrology for 5G Communications in the EMPIR program. The main task is to establish traceability for non-linear vector network analyzer measurements. We also participate as a co-author to a project research topic (Exploiting the Potential of Instrumentation Convergence at RF, Microwave, Millimetre-wave and Terahertz Frequencies) submission for the next EMPIR program.

Since several years we are partners in the GHz Centre, which is a microwave research Centre of excellence financed by VINNOVA and operated by Chalmers in collaboration with industry and SP. Within the GHz Centre at Chalmers we are working on S-parameter measurements on membrane circuits suitable for THz frequencies, cryogenic S-parameters measurements on HEMTs as well as measurements of broadband S-parameters [G1-G3, G5-G7].

Within RMP-FOI the HF laboratory is working on the THz traceability project investigating the need for developing THz metrology at SP. This project has been finance by VINNOVA for a total length period of six months.

References:

[G1] Eunjung Cha,Giuseppe Moschetti,Niklas Wadefalk,Per-Ake Nilsson,Stella Bevilacqua,Arsalan Pourkabirian,Piotr Starski,Jan Grahn, "Two-Finger InP HEMT Design for Stable Cryogenic Operation of Ultra-Low-Noise Ka-Band LNAs," 2017 IEEE MTT-S International Microwave Symposium (IMS).

[G2] S. Gustafsson and M. Thorsell and J. Stenarson and C. Fager, "An Oscilloscope Correction Method for Vector-Corrected RF Measurements," IEEE Transactions on Instrumentation and Measurement vol. 64, no. 9, pp. 2541-2547, 2015.

[G3] A. Prasad and M. Thorsell and K. Yhland and C. Fager, "Symmetry based nonlinear model for GaN HEMTs," 2015 10th European Microwave Integrated Circuits Conference (EuMIC)

[G4] M. Högås and K. E. Rydler and J. Stenarson and K. Yhland, "Analytic Solution of the Magnetic Field and Inductance in a Coaxial Short Circuit," IEEE Transactions on Instrumentation and Measurement, vol. 64, no. 6, pp. 1582-1587, 2015

[G5] J. Hanning, J. Stenarson, K. Yhland, P. J. Sobis, T. Bryllert, and J. Stake, "Single-Flange 2-Port TRL Calibration for Accurate THz S-Parameter Measurements of Waveguide Integrated Circuits," Terahertz Science and Technology, IEEE Transactions on, vol. 4, no. 5, pp. 582-587, 2014

[G6] A. Prasad, C. Fager, M. Thorsell, C. M. Andersson, and K. Yhland, "Symmetrical Modeling of GaN HEMTS," presented at Compound Semiconductor Integrated Circuit Symposium (CSICs), 2014 IEEE, 2014.Date Reference Page 2015-02-25 4 (5) SP Technical Research Institute of Sweden

[G7] A. Prasad, C. Fager, M. Thorsell, C. M. Andersson, and K. Yhland, "Symmetrical Large-Signal Modeling of Microwave Switch FETs," Microwave Theory and Techniques, IEEE Transactions on, vol. 62, no. 8, pp. 1590-1598, 2014

[G8] J. Stenarson, "HFTools - An open source python package for microwave engineering," presented at ARFTG Microwave Measurement Conference (ARFTG), 2014 83rd, 2014.

[G9] J. Stenarson, C. Eio, and K. Yhland, "A calibration procedure for electronic calibration units," presented at ARFTG Microwave Measurement Conference (ARFTG), 2014 84th, 2014.

EM fields

RISE participates in the EMPIR project 15RPT01 RF Microwave aiming for traceable calibration of S-parameters in test environments such as EMC chambers. One of the project tasks is to investigate the possibilities for traceable calibration methods of loop antennas, using VNA techniques.

During the period we also participated in the EMRP project JRP IND60 EMC, focusing on methods to correlate on-site emission measurements with either semi-anechoic or reverberation chamber emission measurements. The level of the Q-value in the on-site test determines how the temporary test site should be treated [F1].

We have an ongoing project for calibration of Antenna Efficiency in Reverberation Chambers. This includes calibration method development with measurement uncertainty analysis and comparison with other relevant calibration methods.

Since 2007 we were active in the Chase center which ended 2016. This work is now continued within the ChaseOn center, which also is an antenna center of excellence financed by Vinnova, and operated by Chalmers in collaboration with industry and research institutes. Within the center RISE participates in development of characterization methods of vehicular 5G systems [F2-F5]. Together with telecom industry we work on evaluation methods of 5G systems, both in-band properties and EMC characteristics.

Within the HiFi Radar Target project we develop automotive radar cross section characterization methods enabling better target characterization, which is needed for advanced driver assistance systems and autonomous driving functions.

RISE is investing in a new communication test chamber for the automotive industry (AWITAR). In parallel the research and measurement group develop over-the-air test methods needed for future vehicle models and investigates the possibilities to use the AWITAR test chamber as an indoor antenna calibration facility [F6].

References:

[F1] Robert VogtArdatjew, Urban Lundgren, Sergio Fernández Romero and Frank Leferink, “OnSite Radiated Emissions Measurements in Semireverberant Environments”, IEEE Transactions on Electromagnetic Compatibility, Year: 2016, Volume: PP, Issue: 99, Pages: 1 0, DOI: 10.1109/TEMC.2016.2623380

[F2] K. Karlsson, M. Larsson, S. Wickström, G. Ledfelt, M. Olbäck, R. Whiton and J. Rogö, “On the Effect of Vertical Spatial Diversity on V2V Communication for Three Different Platooning Scenarios,“ Antennas and Propagation (EuCAP) Proceedings of the 9th European Conference, Lisbon, Portugal, 12-17 April, 2015.

[F3] E.C. Neira, J. Carlsson, K. Karlsson, E.G. Ström, “Combined LTE and IEEE 802.11p Antenna for Vehicular Applications,” Antennas and Propagation (EuCAP) Proceedings of the 9th European Conference, Lisbon, Portugal, 12-17 April, 2015.

[F4] J. Carlsson, K. Karlsson, U. Lundgren, “Characterisation of Cable Feedthrough by Measurements in Nested Reverberation Chambers and Comparison with Simple Theory”, IEEE/EMC Europe 2015, Dresden, Germany, 18-22 Aug., 2015.

[F5] K. Karlsson, J. Carlsson, M. Larsson, C. Bergenhem, “Evaluation of the V2V Channel and Diversity Potential for Platooning Trucks,” Antennas and Propagation (EuCAP) Proceedings of the 10th European Conference, Davos, Switzerland, 11-15 April, 2016.

[F6] J. Carlsson, K. Kilbrandt, A. Nordlöf, C. Karlsson, ”AWITAR Prestudy”, SP Rapport, ISSN 0284-5172 ; 2015:29.

Key personnel

Claes Winzell, Head of department Measurement Science and Technology
Jan Johansson, NMI director
Leslie Pendrill, Optoelectrical metrology
Gunnar Eklund, Electrical primary metrology
Tobias Bergsten, Electrical primary metrology
Valter Tarasso, Electrical primary metrology

Karl-Erik Rydler, Electrical primary metrology
Stefan Svensson, Electrical power metrology
Anders Bergman, Electrical high voltage metrology
Alf Peter Elg, Electrical high voltage metrology
Jonas Cedergren, Electrical high voltage metrology
Allan Bergman, Electrical high voltage metrology
Stella Bevilacqua, Electrical HF and microwave metrology, guided wave
Martin Forsberg, Electrical HF and microwave metrology, free field
Kristian Karlsson, Electrical HF and microwave metrology, free field