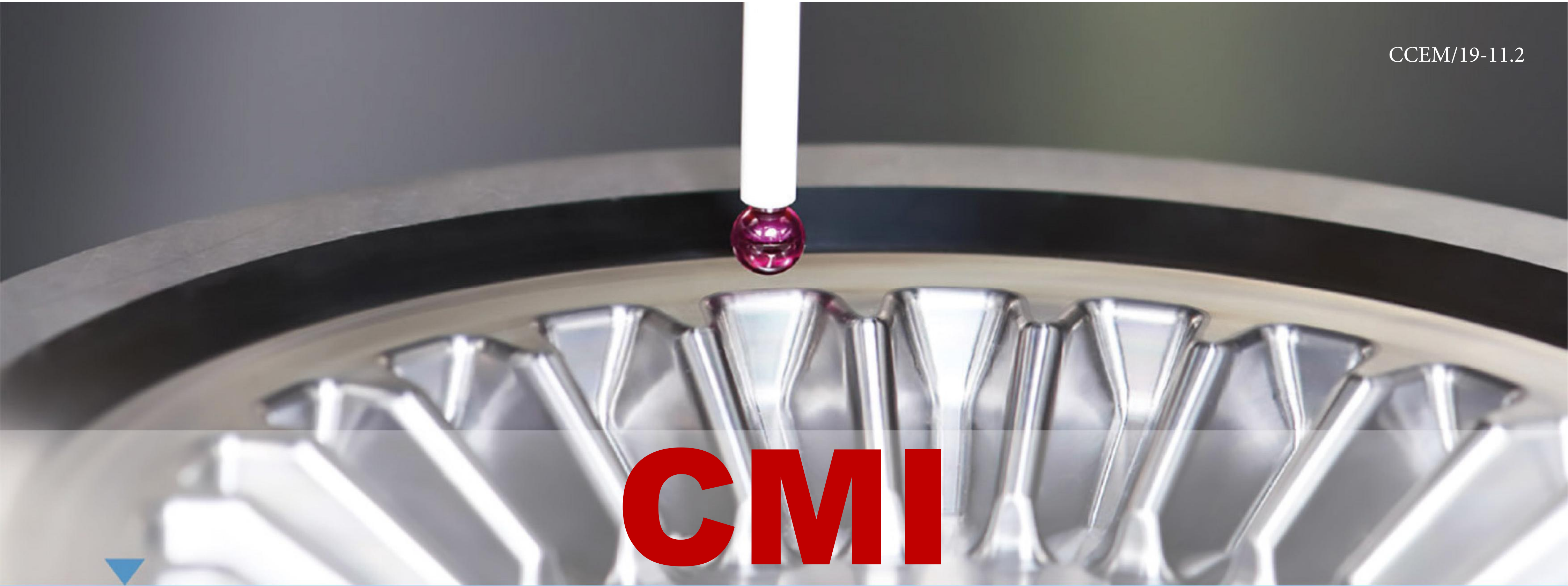
CCEM/19-11.2



CMI

Laboratory of electromagnetic measurements

CZECH METROLOGY INSTITUTE

Jiří Streit

Short history overview

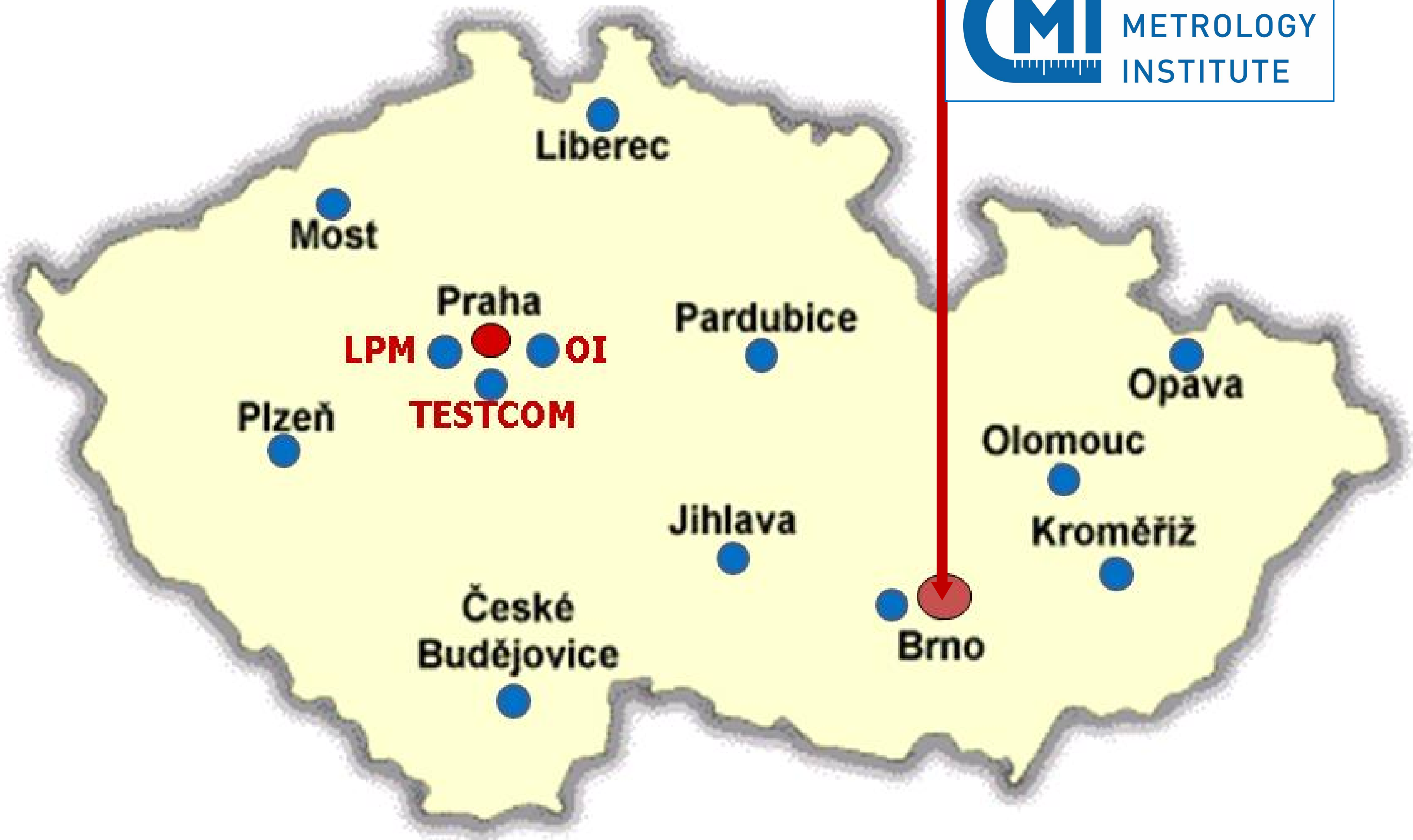
- The federal metrology institute was based in Bratislava, Slovakia.
- CMI was founded in 1993 as a result of the split of the original Czechoslovak Federation on the basis of fragmented Government metrology labs in the CR.
- During the split, property was divided among both parts on the principle of (at that time) present localization.
- The legal status: Government executive agency.
- The mission: to play the role of national metrology institute, especially in fundamental and legal metrology.

Metrology fields in CMI

fundamental metrology	maintenance and development of national standards, research and development in metrology
transfer of units	calibration of standards and measuring instruments,
legal metrology	type approvals of legal metrology instruments, initial and subsequent verification of measuring instruments, metrological supervision, conformity assessment in metrology

Geographical distribution

CZECH
METROLOGY
INSTITUTE



Geographical distribution

Laboratories of electromagnetic measurements are located in Brno and Prague

Brno

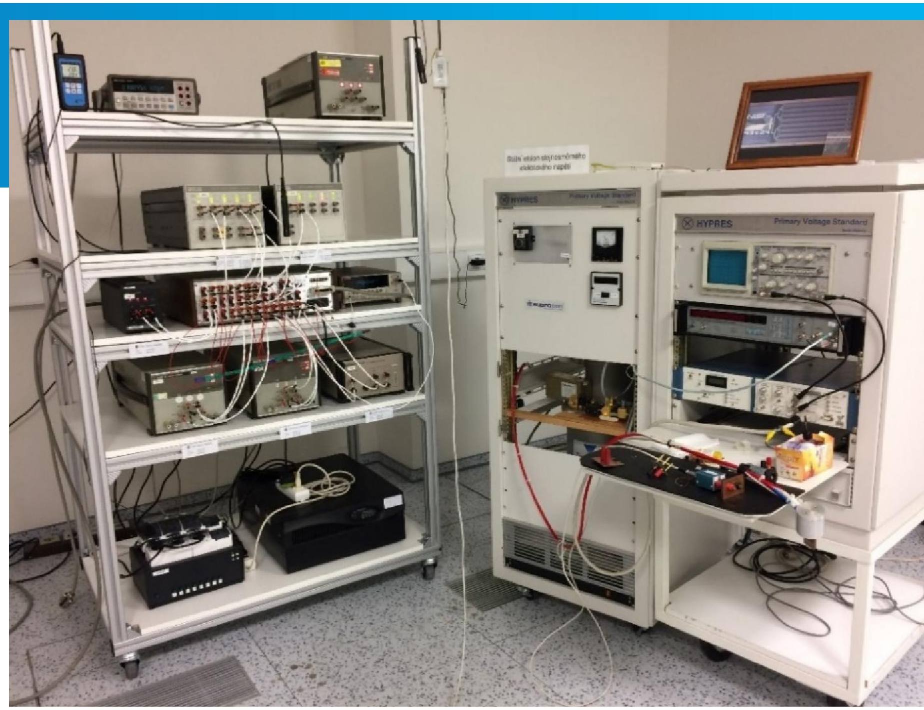
- Department of DC/LF measurements (DCV, ACV, DCI, ACI, impedance, signals power)

Prague:

- Department of primary metrology of electrical resistance
- Department of primary metrology of RF electrical quantities
- Department of electromagnetic quantities (high voltage, high current, magnetic quantities)
- TESTCOM (EMC, radio parameters, electrical safety, antennas)

39 persons working in Electromagnetic Metrology

DC Voltage

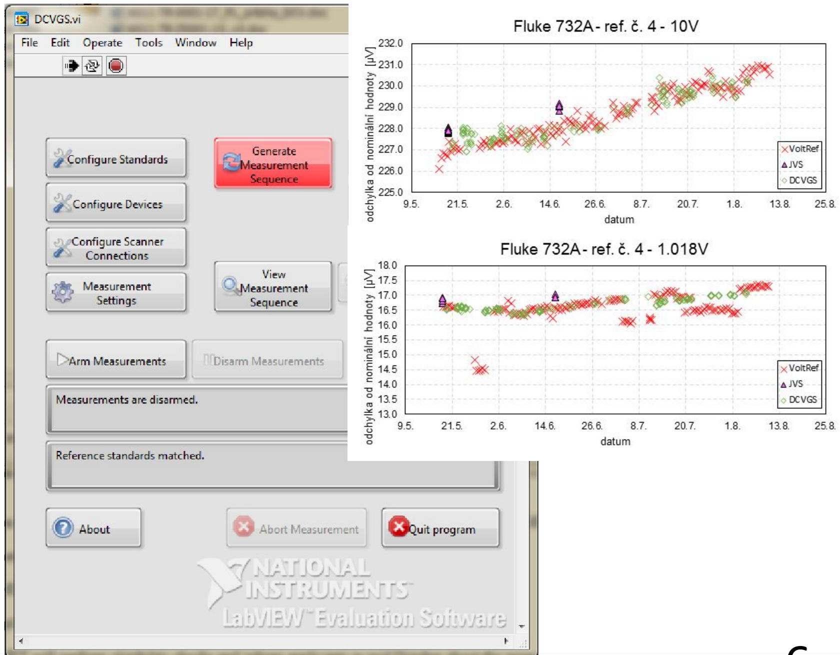


Traceability:
- JVS installed in 2001, Hypress 10 V chip,
- pulse-tube cryocooling, 70 GHz
- bank of 6 ZR standards, own developed
- comparison software

Range 1 mV to 1000 V:
- Tchukotsky’s divider MI 8000
- own unc. calculation
- reference step method (devel. with MSL, RISE)

Comparisons:
- EUROMET.EM.BIPM-K11
- BIPM.EM-K11.a
- BIPM.EM-K10.a
- BIPM.EM-K10.b

	Expanded uncertainty / (µV/V)
1 V	0.10
1.018 V	0.10
10 V	0.06



DC Voltage

Ongoing installation of
Programmable Josephson Voltage Standard

- 10 V chip
- 70 GHz
- pulse-tube cryocooler
- Application Programming Interface for external control

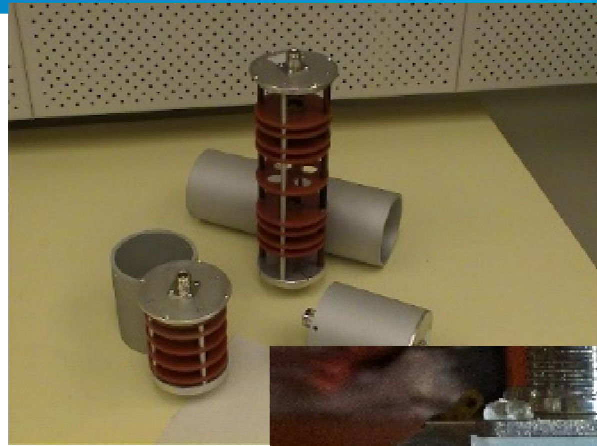
Planned use of the PJVS:

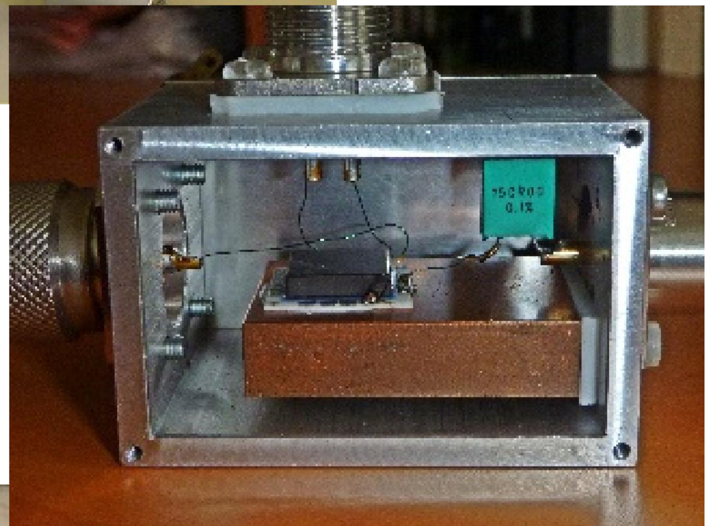
- calibration of calibrators (AC up to 5 kHz)
- basis for power meter
- basis for PMU

AC-DC voltage transfer, AC voltage

Capabilities:

- AC-DC voltage transfer:
  1 mV – 1 kV (10 Hz – 1 MHz)
  unc. 3 – 320 µV/V
  step up/down with RRs and micropots
  starting at 1 V traceable to PTB
- ac voltage:
  - AC-DC transfer standard F792A
    used to <u>calibrate ac sources</u>
    1 mV to 1 kV (10 Hz – 1 MHz)
    unc. 12 to 600 µV/V
  - F792A and micropots
    used <u>to calibrate ACMS F5790A/B</u>
    new CMCs for:
      1.9 mV – 1 kV (10 Hz – 1 MHz)
      unc. 13 – 100 µV/V

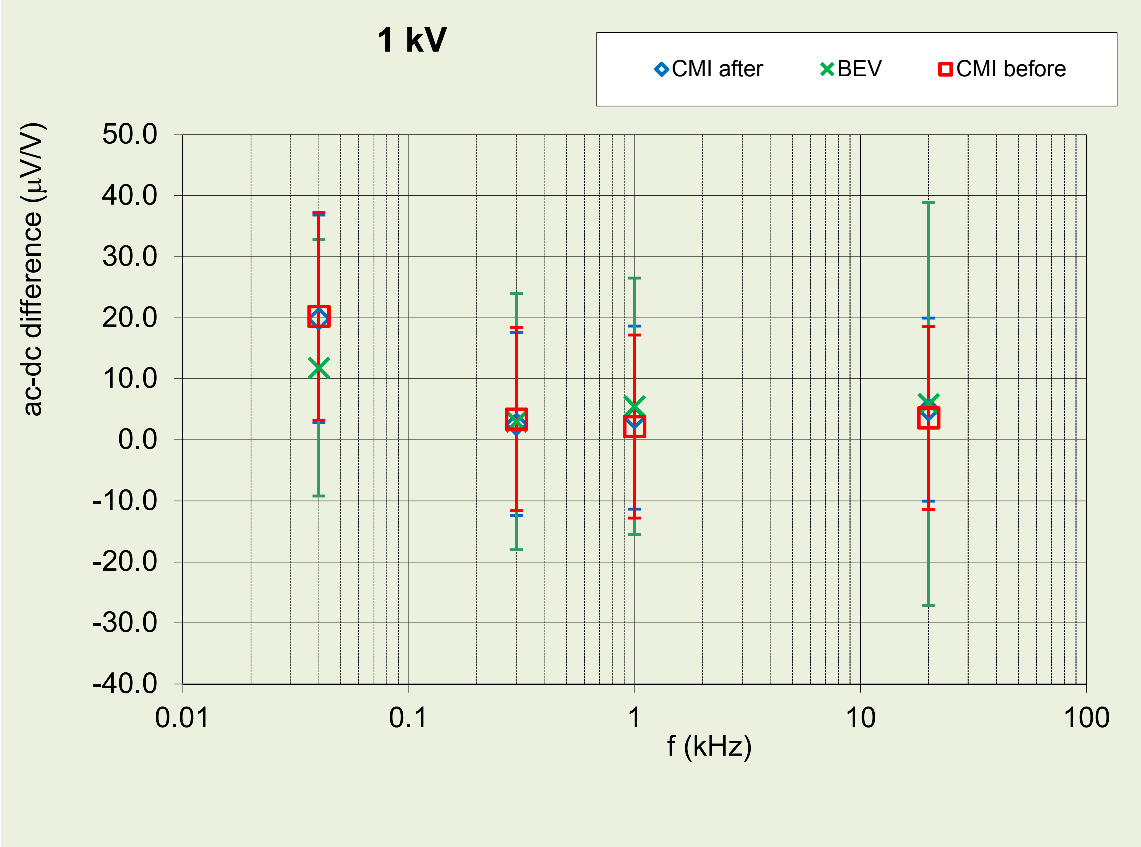




AC-DC voltage transfer, AC voltage

Comparisons:

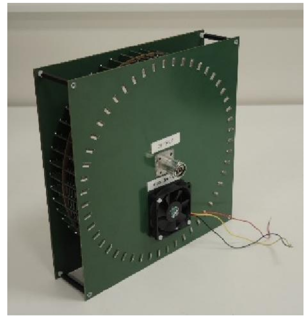
- EUROMET.EM-K9 (2002)
- DUNAMET D43 (2004)
- EUROMET.EM-K11 (2007)
- Bilateral with GUM (2011) and BEV (2016)



Research:

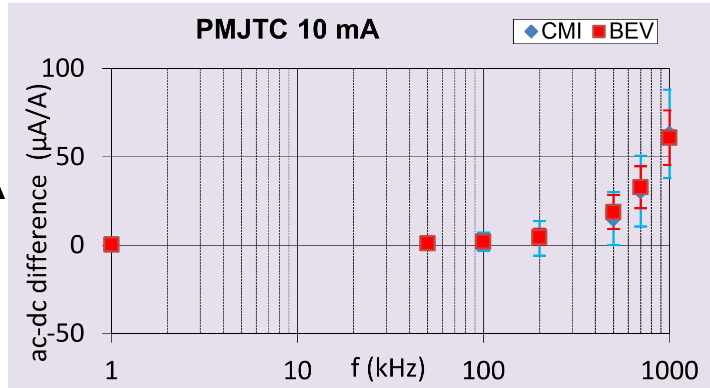
- Ac-dc transfer up to 100 MHz (traceability to PTB):
- 500 mV – 5 V (unc. at 1 V@100 MHz estimated to 3 mV/V)
- Establishing of PJVS in 2019, own traceability of low and mid frequencies

AC-DC current transfer, AC current



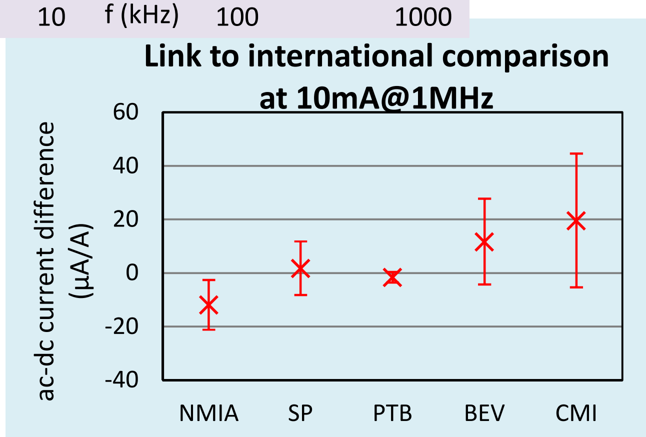
Capabilities:

- AC-DC current transfer:
  1 mA – 100 A (10 Hz – 100 kHz) with unc. 4 – 95 μA/A
  step up with shunts (own traceability - model of a SJTC)
  at 10 mA extension up to 1 MHz (no CMCs yet)
- AC current:
  - Calibration of ac sources and meters by meas. of voltage drop across a shunt
  - developed a set of current shunts 30 mA – 100 A based on lumped element modelling



Comparisons:

- EURAMET.EM-K12 (2012)
- Bilateral with BEV (2016) at 10 mA up to 1 MHz (SJTC and PMJTC as travelling standards)



Research:

- Ac-dc transfer up to 1 A wih extension up to 1 MHz within EMPIR TracePQM project
- Development of new high current shunts with an active cooling reducing the level dependence of DCR and AC-DC difference (CPEM 2016)

DC Resistance

- **Resistance traceability: QHR**
- **Resistance ratio traceability: CCC**
- **National resistance standards:**
  - **2x 1 Ω CSIRO , 100 Ω Tinsley, 10 kΩ ESI, QHE system**
- **DC resistance calibration service**
  - **0.000 01 Ω … 100 TΩ**

	Expanded uncertainty
0.00001 Ω	50
0.0001 Ω	5
0.001 Ω	3
0.01 Ω	2
0.02 Ω	2
0.1 Ω	0.1
1 Ω	0.06
10 Ω	0.02
25 Ω, 50 Ω	0.02
100 Ω	0.012
250 Ω, 300 Ω, 400 Ω	0.02
1000 Ω	0.015
10 kΩ	0.034
100 kΩ	0.2
1 MΩ	0.5

	20 V to 100 V	500 V	1000 V
10 MΩ	7	-	-
100 MΩ	16	-	-
1 GΩ	30	-	-
10 GΩ	70	70	70
100 GΩ	80	75	70
1 TΩ	120	100	80
10 TΩ	550	370	200
100 TΩ	6000	3500	400

The expanded uncertainties given in this table are expressed in μΩ/Ω

- **Resistance bridges calibration service**
  - **0.000 1 Ω … 100 TΩ (under CIPM MRA 0.1 Ω … 1 MΩ)**

0.1 Ω to 100 kΩ	0.011 to 0.1
100 kΩ to 1 MΩ	0.05 to 0.4

The expanded uncertainties given in this table are expressed in 1E-06

DC Resistance

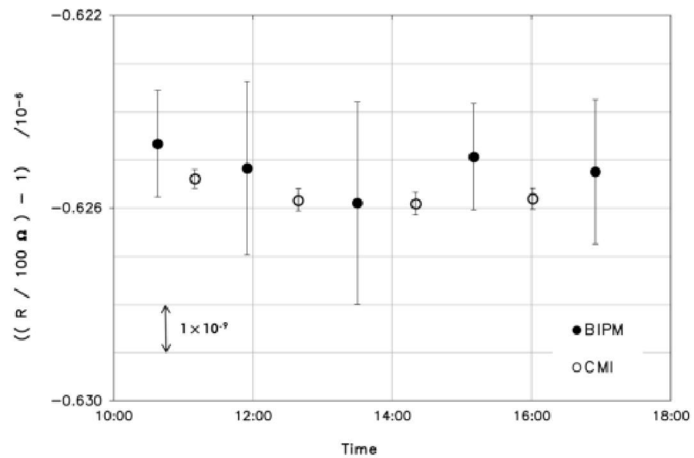
10 succesfull international comparisons since 1998 in the range from 1 Ω up to 100 TΩ.

E.g. comparisons:

- BIPM.EM-K13.a (1 Ω), BIPM.EM-K13.b (10 kΩ)
- EUROMET.EM-K10 (100 Ω)
- EUROMET.EM-K2 (10 MΩ and 1 GΩ)
- EUROMET.EM-S32 (1 TΩ and 100 TΩ)

On-site comparison of QHE standards BIPM.EM-K12 in 2017:

	Degree of equivalence D /10^{-9}	Expanded uncertainty U /10^{-9} (k=2)
$R_{100\Omega}$ in terms of $R_{H}(2)$	**−0.6**	**5.0**
$K1 = R_{10k\Omega}/R_{100\Omega}$	**+1.1**	**4.4**
$K2 = R_{100\Omega}/R_{1\Omega}$	**+3.3**	**6.4**



P. Gournay, B. Rolland, J. Kučera, and L. Vojáčková, “On-site comparison of Quantum Hall Effect resistance standards of the CMI and the BIPM: ongoing key comparison BIPM.EM-K12,” *Metrologia*, vol. 54, no. 1A, p. 1014, 2017

Kučera, J.; Vojáčkova, L. & Chrobok, P. “On aspects of calibration of DC resistance ratio bridges,” CPEM, 2016, 1-2

Impedance and AC voltage ratio

National standard of capacitance:

- 4x AH11A 100 pF + 1x 10 pF, traceable to BIPM, uncertainty (k = 2) 90 nF/F

Impedance measurements range:

- CMCs for *R*, *L*, *C* up to 20 kHz, uncertainty down to 0.5 ppm
- CMCs for *D* and *phase angle* down to < 1 µrad
- CMCs for high capacitances (10 mF)
- Measurement range up to 10 MHz

Digital sampling setup for cal. of strain gauge calibrators:

- Uncertainty (k = 2) 7 to 20 nV/V for ratios < 2 mV/V

Digital phase shift measurements:

- CMCs down to 0.001°
- CMCs up to 10 MHz
- Extension up to 100 MHz in progress

Total harmonic distortion measurements:

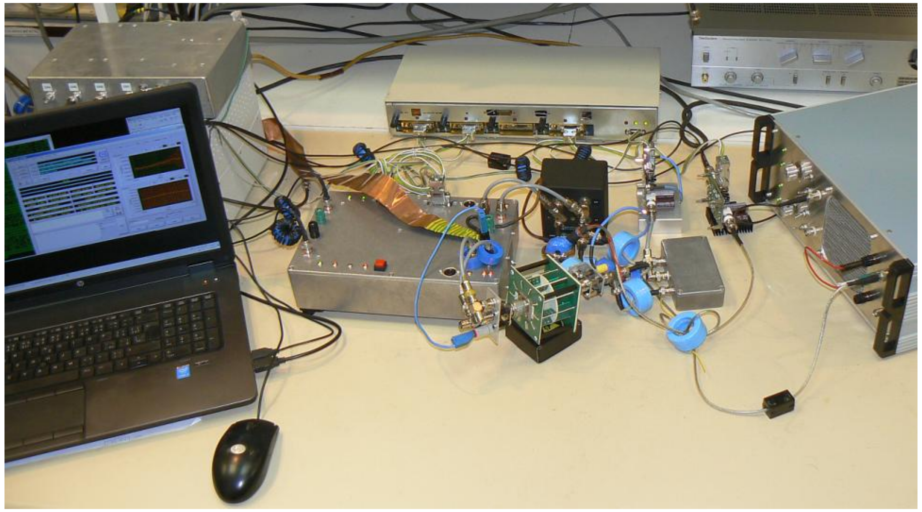
- Calculable THD standard
- CMCs down to 0.0005% and frequencies up to 100 kHz

S. Mašláň, M. Šíra, T. Skalická, "Digital Sampling Setup for Calibration of Strain Gauge Bridge Calibration Unit BN100", CPEM 2018, Paris, 2019, pp. 1-2

Impedance – R&D in low impedance

Development of sampling digital Z bridges:

- Low impedance down to mΩ range
- Full complex plane
- Uncertainty (k = 2) ~50 µΩ/Ω and < 350 µrad at 1 MHz
- Comparison with errors < 30 µΩ/Ω at 1 MHz
- Extension to 10 MHz in progress
- Special ultra low-Z bridges for fr. down to 10 mHz

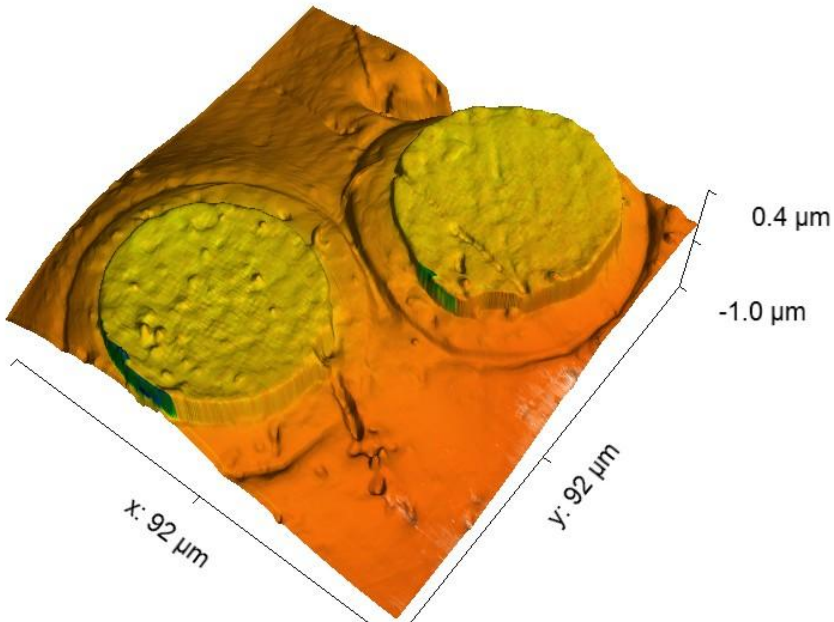


RVD calibration up to 1 MHz:

- Uncertainty (k = 2) ~100 µV/V

Calculable phase angle standards:

- Nominal resistance 6 to 200 Ω
- Uncertainty (k = 2) < 110 ps at 1 MHz
- Comparison with errors < 55 ps



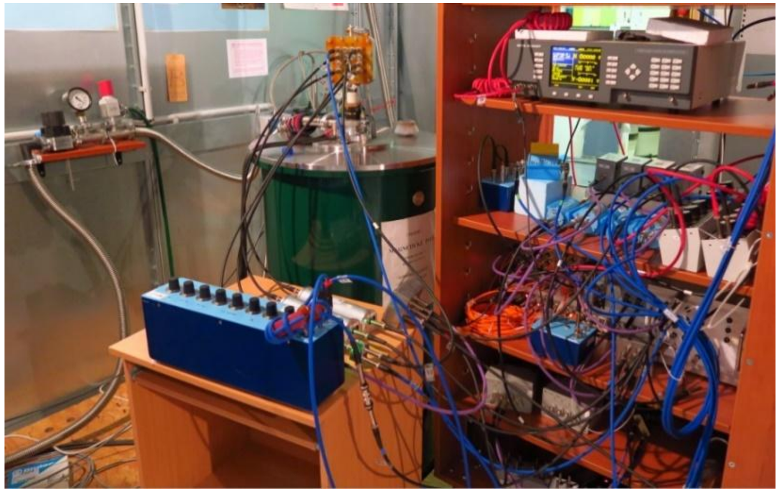
European Research projects:

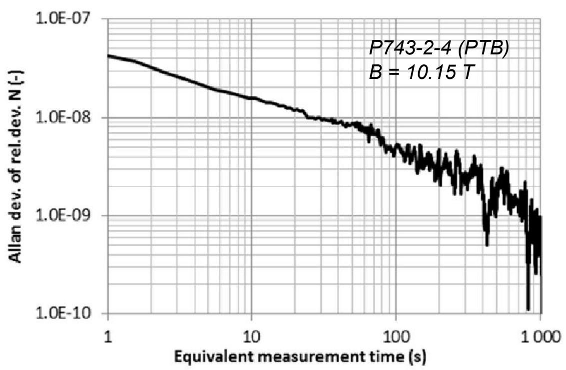
- 17IND10 – Lithium Batteries for Second Life Applications

S. Mašláň, M. Šíra, T. Skalická, "Four Terminal Pair Digital Sampling Impedance Bridge up to 1 MHz", *CPEM 2018*, Paris, 2019, pp. 1-2
S. Mašláň, M. Šíra, T. Skalická, "Progress on Simple Resistance Standard with Calculable Time Constant", CPEM 2018, Paris, 2019, pp. 1-2
S. Mašláň, M. Šíra, T. Skalická, "Precision Buffer with Low Input Capacitance", CPEM 2018, Paris, 2019, pp. 1-2

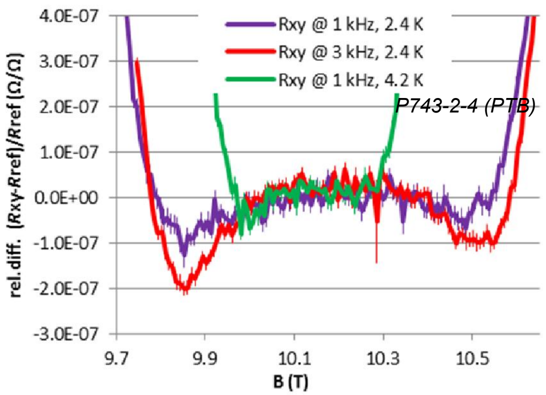
Impedance – R&D Quantum standards

- **Digitally assisted and fully digital bridges for primary metrology**
- **Realization of AC QHE**
- **Ongoing work on traceability of C to AC QHE**





Allan deviation of 1:1 ratio measurement of QHR against OF12k9 CTU at a frequency of 1 kHz and current of 23 μA



R_{xy} plateau shape at different temperatures and frequencies measured at current 23 μA (u_A bars with cov. prob. ~95 %). Value of R_{ref} corresponds to ac resistance observed in the middle of each plateau

J. Kučera and J. Kováč, “A Reconfigurable Four Terminal-Pair Digitally Assisted and Fully Digital Impedance Ratio Bridge,” *IEEE Trans. Instrum. Meas.* , vol. 67, no. 99, pp. 1–8, 2018.

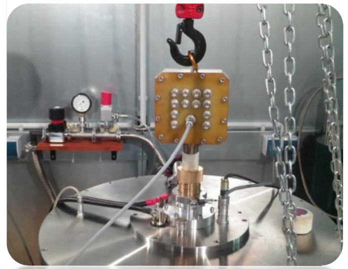
J. Kučera, P. Svoboda, and K. Pierz, “AC and DC Quantum Hall Measurements in GaAs Based Devices at Temperatures up to 4.2 K,” *IEEE Trans. Instrum. Meas.*, 2018.

J. Kučera and P. Svoboda, “Development of Ac Quantum Hall Measurements at CMI,” in Precision Electromagnetic Measurements (CPEM 2018), 2018 Conference on , 2018.

Impedance – R&D of special hardware

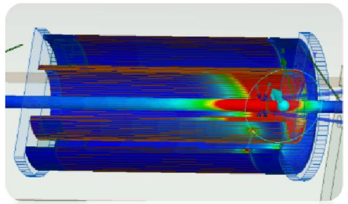
Research and development:

- Precise isolated generators SWG for digital impedance bridges
- Coaxial multiplexers
- Complete impedance DA/FD digital bridges
- Cryogenic AC-QHR probe
- Custom mK air bathes TBx with protective atmosphere
- Impedance standards with calculable frequency dependence



European Research projects:

- JRP-s03 GraphOhm - Quantum resistance metrology based on graphene (2013-2016)
- JRP-s07 AIM QuTE - Automated impedance metrology extending the quantum toolbox for elektricity (2013-2016)
- 17RPT04 VersICaL - A versatile electrical impedance calibration laboratory based on digital impedance bridges (2018-2021)
- 18SIB07 GIQS - Graphene Impedance Quantum Standard (2019-2022)



EMPIR EURAMET GraphOhm AIM QuTE VersICaL GIQS

Power measurement

Traceability:

HEG comparator K2005
- Voltage range: 6 – 530 V
- Current range: 5 mA – 100 A
- Frequency range: 45 – 65 Hz
- CMC for single phase 100 µW/VA
- CMC for three phase 200 µW/VA
- ongoing comparison EURAMET.EM.K5
- Our new CMC after comparison we estimate to 20 µW/VA

Sampling standard:
- based on HP/Agilent/Keysight **3458** or NI **5922**
- own construction of shunts and dividers
- data processing based on software mostly
- developed in CMI
- Voltage range: 4 – 560 V
- Current range: 5 mA – 100 A
- 16 – 800 Hz

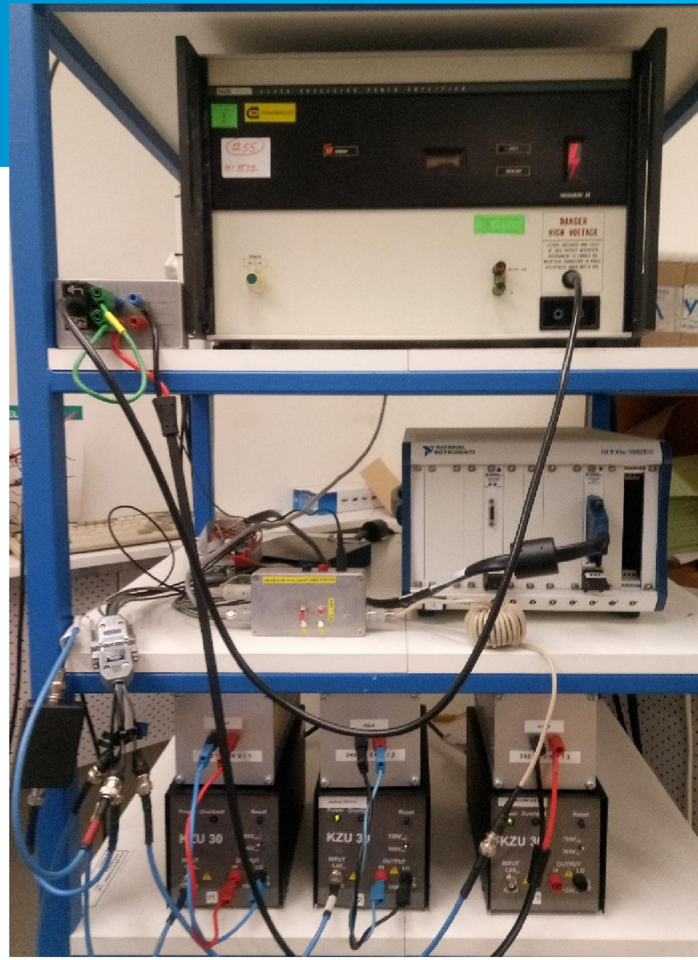
Power measurement

Wideband power:

- Multiphase setup based on PXI 5922
- Traceable to 100 kHz
- 1 MHz range in development (EMPIR TracePQM)

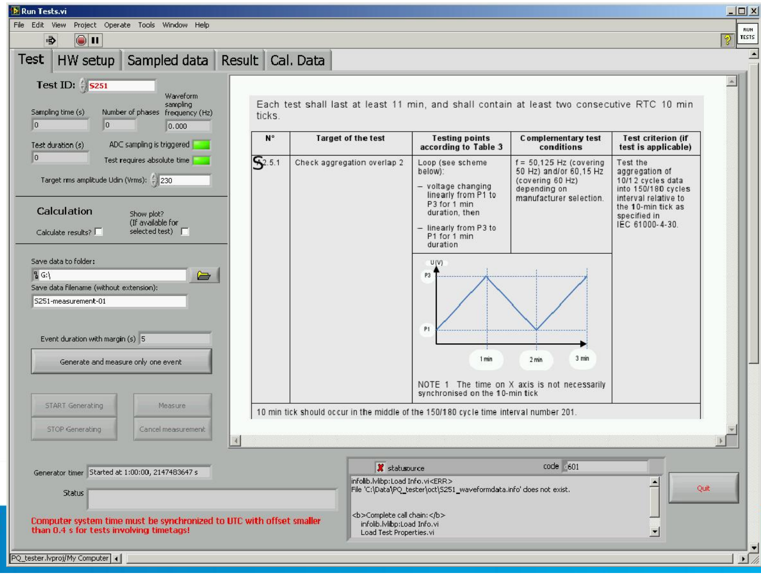
Power quality measurements:

- implemented verification of PQ meters
- according standard IEC 62586-2
- class A,S, 150 tests
- 3 phase system based on Fluke 6100, DAC
- ADC NI 5922, dividers, shunts, time standard
- voltage, current, (inter)harmonics, events, RVC,freq.



Phasor Measurement:

- Unit Calibration system
  Fluke 6135A PMU/CAL



Power meas – Legal metrology

Verification of electricity meters

- Verification of all types of electricity meters
- Performance of statistical selection tests
- Calibration of electrical power measurement devices

Notified Body CMI, No. 1383, according Directive 2014/32/EU of the European Parliament and of the Council

Details of technical requirements are described in harmonized standards (norms) EN 50470, 62052 family

Member of Welmec: working group WG7, WG11

Power meas – Legal metrology

CMI has 3 test benches for verification:

- type EMH ENZ 200.3, manufacturer Landis+Gyr – with 5 measuring positions,
- type ELMA 8310B, manufacturer Applied Precision - with 20 measuring positions,
- type PTS3.3C, manufacturer Landis+Gyr – with 1 measuring position.

type EMH ENZ 200.3

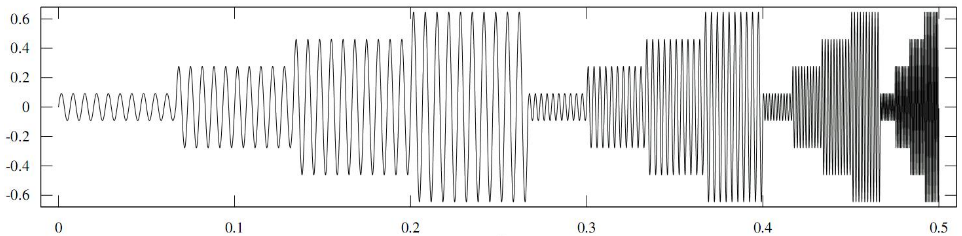
type ELMA 8310B

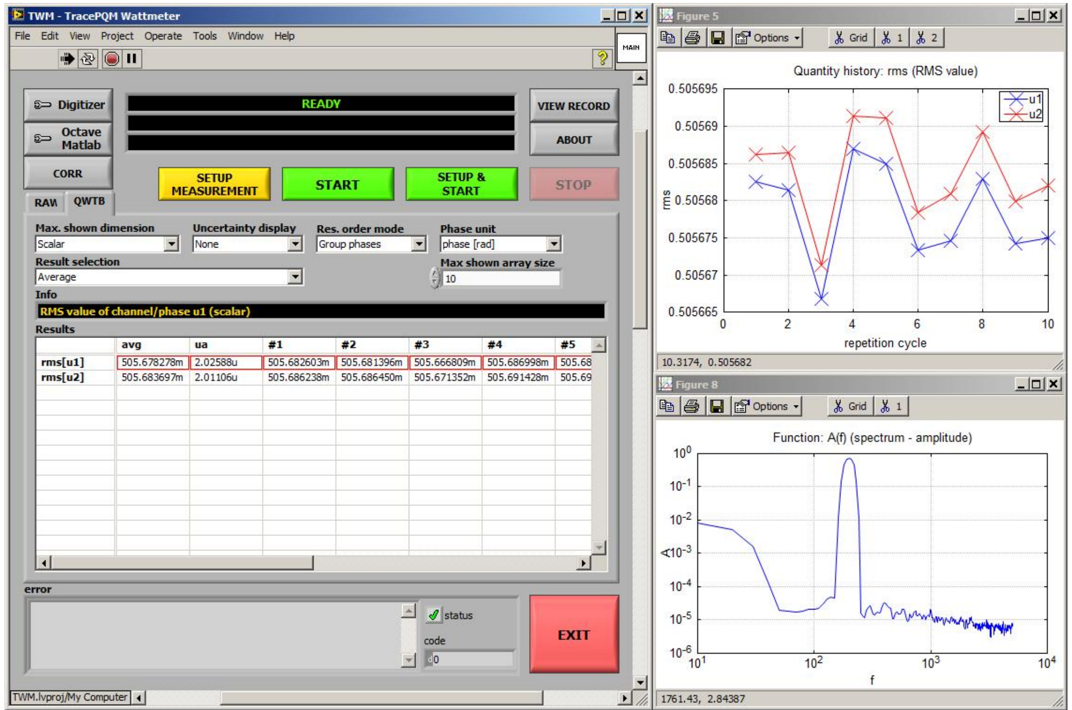
type PTS3.3C

Other research & developement

- Measurement models and unc. calculations of the Tchukotsky's divider MI 8000
- With NSL, RISE: dev. of Reference Step Method using HP 3458A and calibrator

- Developement of algorithms and control software
  - QWTB: Q-Wave toolbox – collection of algorithms for sampled data
  - TWM: general power measurement system
    - any number of phases
    - any digitizer
    - multiple algorithms
  - ADC calibration methods using JAWS





https://qwtb.github.io/qwtb/
https://github.com/smaslan/TWM
Šíra, Kieler, Behr: A novel method for calibration of ADC, DOI: 10.1109/TIM.2018.2888918

Participation in EMRP/EMPIR projects

- Q-Wave – developement of algorithm toolbox
- GraphOhm – cryocooled graphene QHR
- SmartGrids I – load identification methods
- SmartGrids II – simulation and uncertainty calculation of PMU
- RoCoF – simulation and uncertainty calculation of ROCOF measurement
- ACQ-PRO – propagation of AC quantum voltage standards
- QuADC – sampled data algorithms, measurement control
- MyRails – uncertainty calculations of on-board measurement systems
- TracePQM – developement of general power measurement standard
- DIG-AC – validation of algorithms and uncertainty evaluation
- AIM QuTE - Automated imp. metrology extending the quantum toolbox for electricity
- VersICaL - A versatile electrical imp. calibration laboratory based on digital impedance bridges
- GIQS - Graphene Impedance Quantum Standard

High Voltage and Current

NATIONAL STANDARD OF AC CURRENT RATIO

- GROUP STANDARD FORMED BY 3 CURRENT COMPARATORS, TRANSFORMER TEST SET AND BURDEN
- MEASURING RANGE (0.5 – 10 000) A/(5 & 1) A
- CMCs: 20 μA/A & 20 μrad @ 50 Hz

Transformer test set Tettex 2767

Electronic current burden Tettex 3691

Compensated current comparator KPK2 (5 – 1 200) A/5 A, uncertainty 10 ppm

Current comparators Tettex 4761 & Tettex 4764

NATIONAL STANDARD OF AC VOLTAGE RATIO

- GROUP STANDARD FORMED BY INSTRUMENT VOLTAGE TRANSFORMERS, CAPACITIVE AND ELECTRONIC DIVIDERS, TRANSFORMER TEST SET AND BURDEN
- MEASURING RANGE (500 – 400 000) V/(5 - 250) V
- CMCs: 60 μV/V & 60 μrad @ 50 Hz

Transformer test set Tettex 2767

Electronic voltage burden Tettex 3695

Electronic voltage divider Tettex 4860

Standard instrument voltage transformers and capacitive divider Tettex up to 100 kV

Capacitive divider Tettex up to 400 kV

Magnetic quantities

NATIONAL STANDARD OF MAGNETIC FLUX

- GROUP STANDARD
- NOMINAL VALUE OF 10 mWb/A
- CMC: 0.024% (calibration of magnetic flux standard with nominal value of 9.95 mWb to 10.05 mWb by direct comparison with national standard of magnetic flux) 0.1% (calibration of magnetic flux standard with nominal value of 1 mWb up to 100 mWb by direct comparison with national standard of magnetic flux)

NATIONAL STANDARD OF MAGNETIC FLUX DENSITY

STANDARD METHOD OF NMR FORCED PRECESSION:
- measuring range 20 mT up to 3.5 T
- CMC: 0.01%

PRIMARY COIL STANDARD (BARKER TYPE SOLENOID):
- quartz frame, single layer winding in four sections
- nominal value 0.6 mT/A
- CMC: 0.007% (calibration of coil standards by direct comparison with national coil standard)

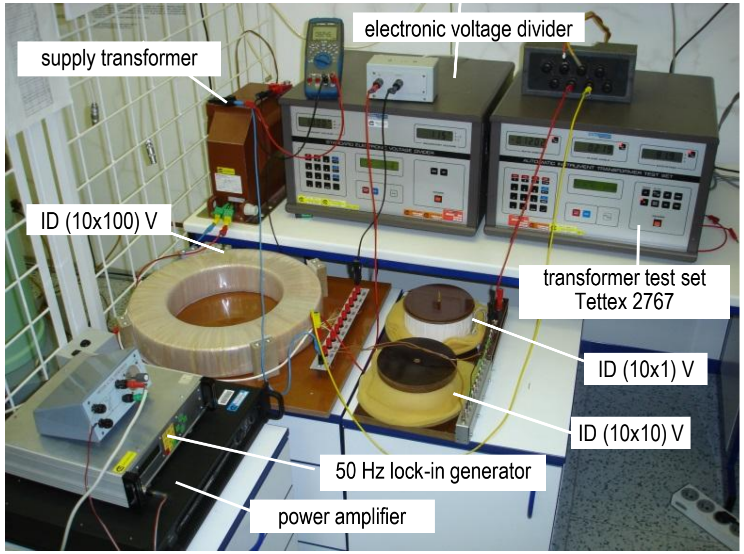
STANDARD METHOD OF NMR WITH FLOWING WATER (NUTATION METHOD):
- measuring range 0.1 mT up to 50 mT
- CMC: 0.01%

Research & Developement

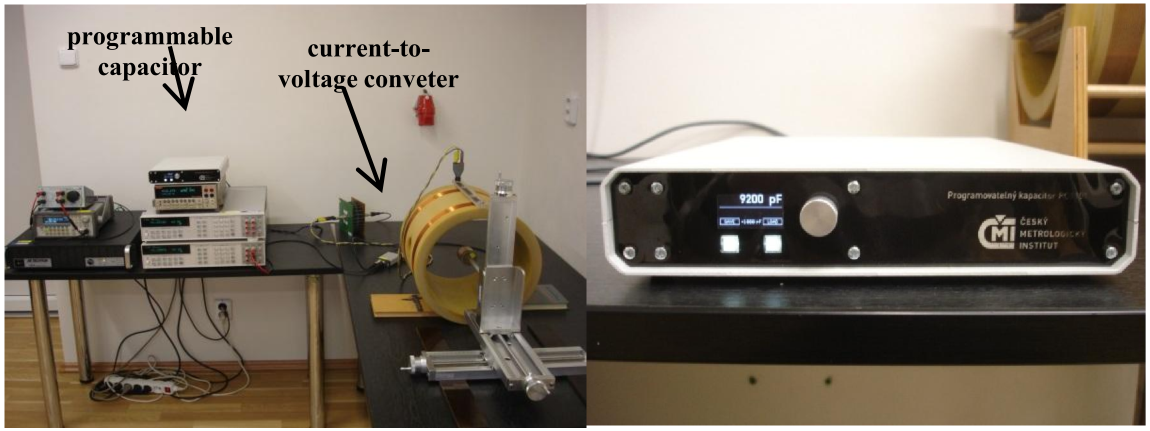
SPECIAL CALIBRATIONS & RESEARCH

Current loop for AC current meter testing up to 30 kA

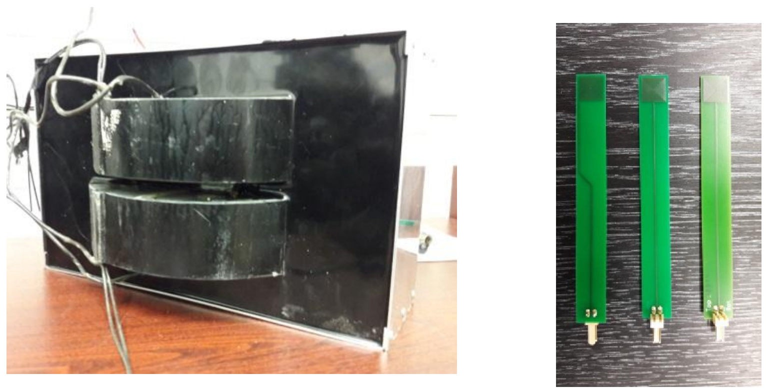
AC/DC voltage divider up to 20 kV
standard uncertainty 40 ppm



Workplace for electronic voltage testing using inductive dividers up to 1 kV (ID)



Setup for AC amplitude MFD measurement/generation up to 150 kHz (left) and programmable capacitor array PC1101 (right)



AC electromagnet (left) and PCB search coils (right) used in system for transversal Hall probe calibration up to 1 T at a low frequencies (30 Hz to 70 Hz)

Research & Developement

PARTICIPATION IN EUROPEAN PROJECTS

EMRP

- ENG52 - SmartGrid II - Measurement Tools for Smart Grid Stability and Quality
- ENG61 – Future Grid - Non-conventional voltage and current sensors for future power grids
- IND08 – MetMags - Metrology for Advanced Industrial Magnetics

EMPIR

- 14IND08 ElPow - Metrology for the electrical power industry
- 15SIB06 - NanoMag - Nano-scale traceable magnetic field measurements

PARTICIPATION IN INTERNATIONAL COMPARISONS

- EUROMET 473 and 612 - Comparison of the measurement of current transformers (CTs) – Pilot NPL
- EUROMET 599 - International comparison of AC voltage ratio standards – **Pilot CMI**
- EURAMET 1081- Comparison of the measurements of current transformers – Pilot BIM
- EURAMET 1187 - Comparison of instrument current transformers up to 10 kA – **Pilot CMI**
- EURAMET 1217 - Comparison of High DC Current Ratio Standard – Pilot INRIM
- EURAMET 446 - International comparison of magnetic flux density by means of field coil transfer standards – Pilot PTB
- EURAMET 597 - Intercomparison of magnetic flux by means of coil transfer standard – **Pilot CMI**
- CCEM.M-K1 - Magnetic flux density by means of transfer standard coil – Pilot PTB
- COOMET 516 - Measurements of magnetic loss power in electrical steel at the frequency of 50 Hz and 60 Hz – Pilot UNIIM
- EURAMET.EM.RF-S27 - Antenna factor for loop antennas, 10 Hz to 10 MHz – Pilot METAS
- P1-APMP.EM-S14 - Comparison of Earth-Level DC Magnetic Flux Density – Pilot VNIIM
- EURAMET.EM.M-S2 - Polarization and specific total power loss in soft magnetic materials – Pilot PTB

PUBLICATIONS

1. Draxler, K.; Styblíková, R.: Magnetic Shielding of Rogowski Coils. IEEE Transactions on Instr. and Meas. 2018, 67(5), 1207-1213. ISSN 0018-9456.
2. Draxler, K.; Styblíková, R.; Hlaváček, J.; Rietveld, G. et al.: Results of an International Comparison of Instrument Current Transformers up to 10 kA at 50 Hz Frequency. 2018 Conf. on Precision Electromagnetic Measurements (CPEM 2018). Vail, Colorado: IEEE Instrumentation and Measurement Society, 2018. ISSN 2160-0171. ISBN 978-1-5386-0974-3.
3. Draxler, K.; Styblíková, R.: Calibration of AC clamp Meters. IEEE Trans. on Instr. and Measurement. 2016, 65(5), 1156-1162. ISSN 0018-9456.
4. Ripka, P.; Draxler, K.; Styblíková, R.: DC-Compensated Current Transformer. Sensors. 2016, 16(1), 114-123. ISSN 1424-8220.
5. Bauer, J.; Ripka, P.; Draxler, K.; Styblíková, R.: Demagnetization of Current Transformers Using PWM Burden. IEEE Trans. on Magnetics. 2015, 51(1), ISSN 0018-9464.
6. Ripka, P.; Draxler, K.; Styblíková, R.: AC/DC Current Transformer With Single Winding. IEEE Trans. on Magnetics. 2014, 50(4), 1-4. ISSN 0018-9464.
7. Draxler, K.; Styblíková, R.; Rada, V.; Kučera, J.; Odehnal, M.: Using a Current Loop and Homogeneous Primary Winding for Calibrating a Current Transformer. IEEE Trans. on Instr. and Meas. 2013, 62(6), 1658-1663. ISSN 0018-9456.
8. Ripka, P.; Draxler, K.; Styblíková, R.: Measurement of DC Currents in the Power Grid by Current Transformer. IEEE Trans. on Magnetics. 2013, 49(1), 73-76. ISSN 0018-9464.
9. Draxler, K.; Styblíková, R.; Hlaváček, J.; Procházka, R.: Calibration of Rogowski Coils with an Integrator at High Currents. IEEE Trans. on Instr. and Meas. 2011, 60(7), 2434-2438. ISSN 0018-9456.
10. M. Ulvr: Setup for generating an AC magnetic field from 3 kHz up to 100 kHz, IEEE Transaction on Magnetics, vol. 51, No. 1, January 2015.
11. M. Ulvr, J. Polonský: Generating an AC amplitude magnetic flux density value up to 150 μT at a frequency up to 100 kHz, Journal of Electrical Engineering, vol. 68, No. 3, 2017.
12. M. Ulvr, J. Kupec: Improvements to the NMR Method with Flowing Water at CMI, IEEE Transaction on Instrumentation and Measurement, vol. 67, No. 1, 2018, pp. 204-208.
13. M. Ulvr: Design of PCB Search Coils for AC Magnetic Flux Density Measurement, AIP Advances, vol. 8, no. 4, pp. 047505-1 - 047505-9, 2018.

RF electrical quantities

National standard of RF power:
frequency range up to 40 GHz (up to 50 GHz under preparation)

- calibration factor of power sensors CMC 0.004 to 0.02
- absolute power level (-100 to 55) dB(mW) CMC (0.05 to 0.12) dB
- RF attenuation (0 to 110) dB CMC (0.02 to 0.57) dB

National standard of RF reflection and transmission coefficient (scattering parameters):
frequency range up to 26.5 GHz (up to 50 GHz under preparation)

- N-type connector CMC (refl. coef) 0.004 to 0.038
- PC-7 connector CMC (refl. coef) 0.002 to 0.004
- 3.5 mm connector CMC (refl. coef) 0.004 to 0.008

National standard of RF electromagnetic field:

- E-field in anechoic chamber up to 100 V/m, 18 GHz CMC 0.8 dB
- H-field up to 30 MHz CMC (0.14 to 0.8) dB
- E-field in TEM cells up to 3 GHz CMC (0.5 to 1) dB
- E-field in waveguide (1 to 2.5) GHz CMC 0.4 dB
- Antenna gain (horn antenna) up to 18 GHz CMC 0.25 dB
- Antenna factor (loop antenna) up to 30 MHz CMC (0.14 to 1) dB

RF electrical quantities

Key and supplementary comparisons (in recent 10 years):

Electromagnetic field:

- Supplementary comparison EUROMET.EM.RF-S25, Comparison of Electrical Field Strength Measurements above 1 GHz (ČMI pilot laboratory)
- BIPM Key Comparison CCEM.RF-K23.F, On-axis Gain in Ku Band at 12.4, 15 and 18 GHz
- BIPM Key Comparison CCEM.RF-K24.F, E-field measurement at frequencies of 1 GHz, 2.45 GHz, 10 GHz and 18 GHz and at indicated field levels of 10 V/m, 30V/m and 100 V/m
- Supplementary comparison EURAMET.EM.RF-S27, Antenna Factor for Loop Antennas

RF reflection and transmission cooefficient (scattering parameters):

- BIPM Key Comparison CCEM.RF-K5c.CL, Scattering Coefficients by Broad-Band Methods 100 MHz - 33 GHz - 3.5 mm connector
- EURAMET comparison 1426, Comparison of S-parameter Measurements in N-type connector devices, in the frame of EMPIR 15RPT01 project

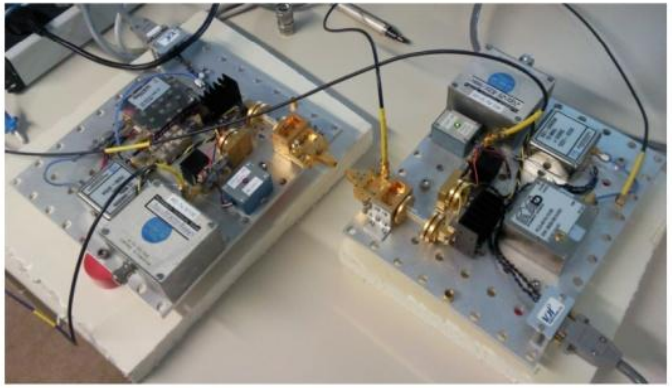
RF power and attenuation:

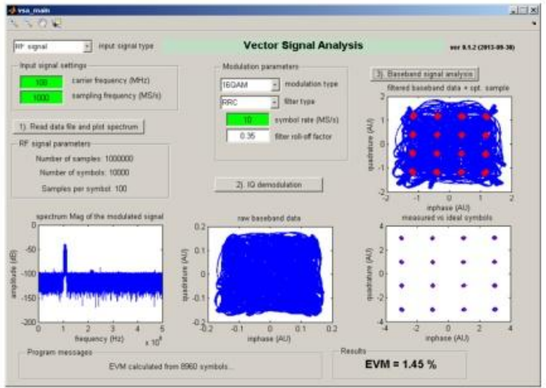
- CIPM Key Comparison CCEM.RF-K26, Attenuation at 18 GHz, 26.5 GHz and 40 GHz using a step attenuator

RF electrical quantities

Projects:

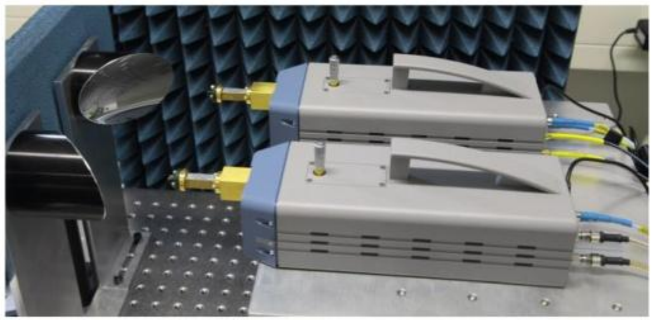
EMRP IND16 Ultrafast http://www.ptb.de/emrp/ultrafast.html

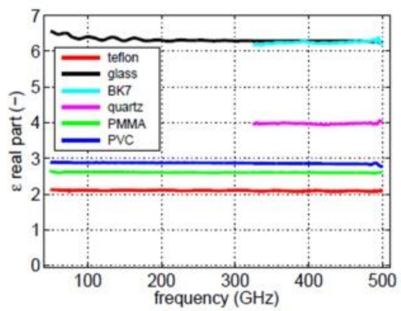




traceable measurement methods for wireless communications (traceable calibration of vector signal generators and analyzers, traceable measurement of error vector magnitude (EVM)

EMRP NEW07 THz Security http://www.ptb.de/emrp/thz_security.html



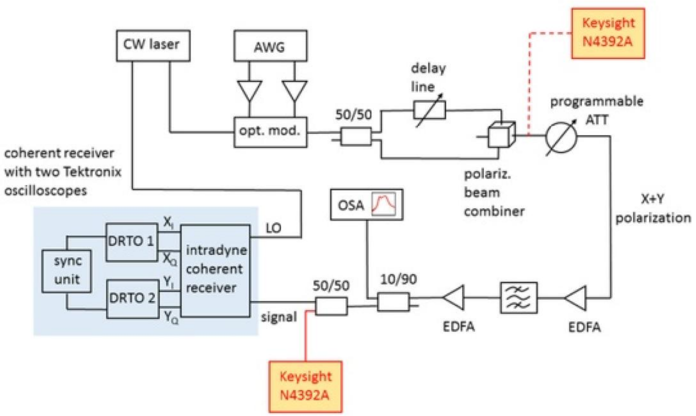


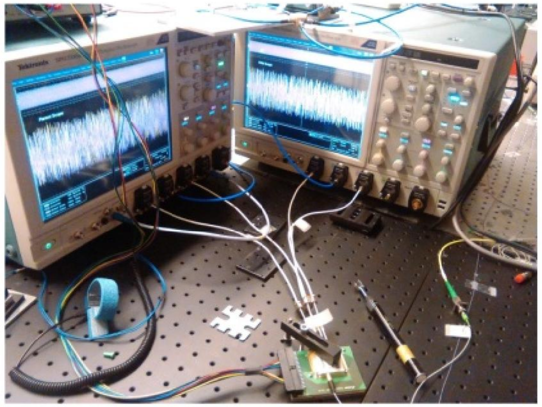
cooperation on characterization of a frequency-domain free-space VNA spectrometer 50-500 GHz, traceable measurement of material properties (complex permittivity)

RF electrical quantities

Projects:

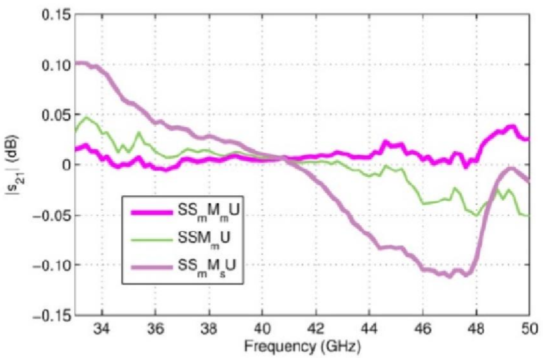
EMRP IND51 MORSE http://projects.npl.co.uk/emrp-ind51-morse/ (2013-2016)

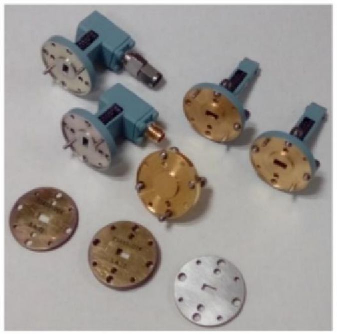




cooperation on traceability for multilevel optical modulation formats (QPSK, 16QAM), traceable measurement of EVM for 100G/400G

EMRP SIB62 HF Circuits http://www.hfcircuits.org/ (2013-2016)



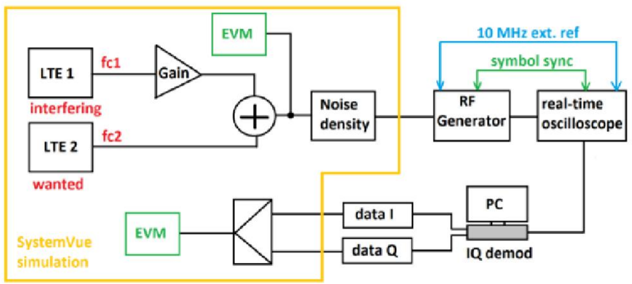


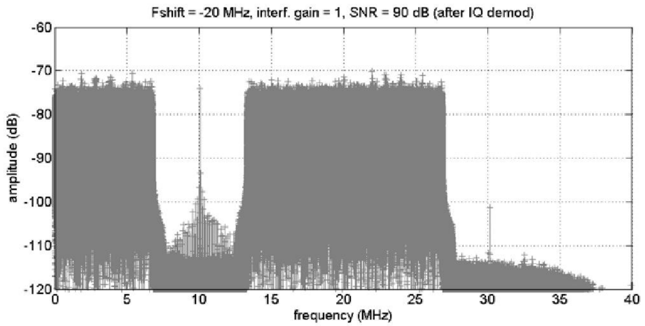
traceability for s-parameters at millimeter-wave frequencies; traceability for balanced VNA measurements

RF electrical quantities

Projects:

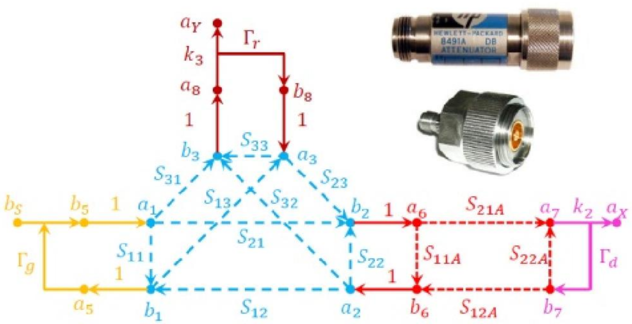
EMPIR MET5G http://empir.npl.co.uk/met5g/ (2015-2018)

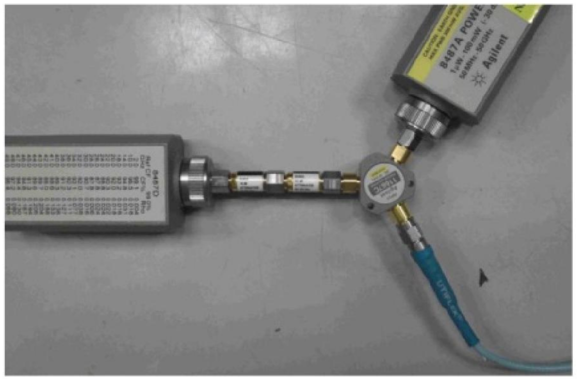




traceability for signal-to-interference-plus-noise ratio (SINR) in 5th generation wireless networks (5G); traceability for wideband nonlinear measurements

EMPIR RFMicrowave http://rfmw.cmi.cz/ (2016-2019)





improvement of measurement capabilities of RF power, s-parameters and EMC; cooperation with other European national metrology institutes

Testing laboratory

TESTING & CALIBRATION, CERTIFICATION

- Testing in Accredited laboratory (EMC , radio parameters, electrical safety)
  - According to generic, product (EN), OIML, ETSI and international Standards
  - Of broad range of products : legal metrology, multimedia, IT, alarm, automotive, railroad applications, Med, House
- Calibration of Antennas (loop, biconical, log-periodic, hybrid, horn, special)
  - According to ANSI, SAE ARP standards
  - Frequency range 9 kHz – 18 GHz
- Certification (RED 2014/53/EU) – Notified Body No.1383

Testing laboratory

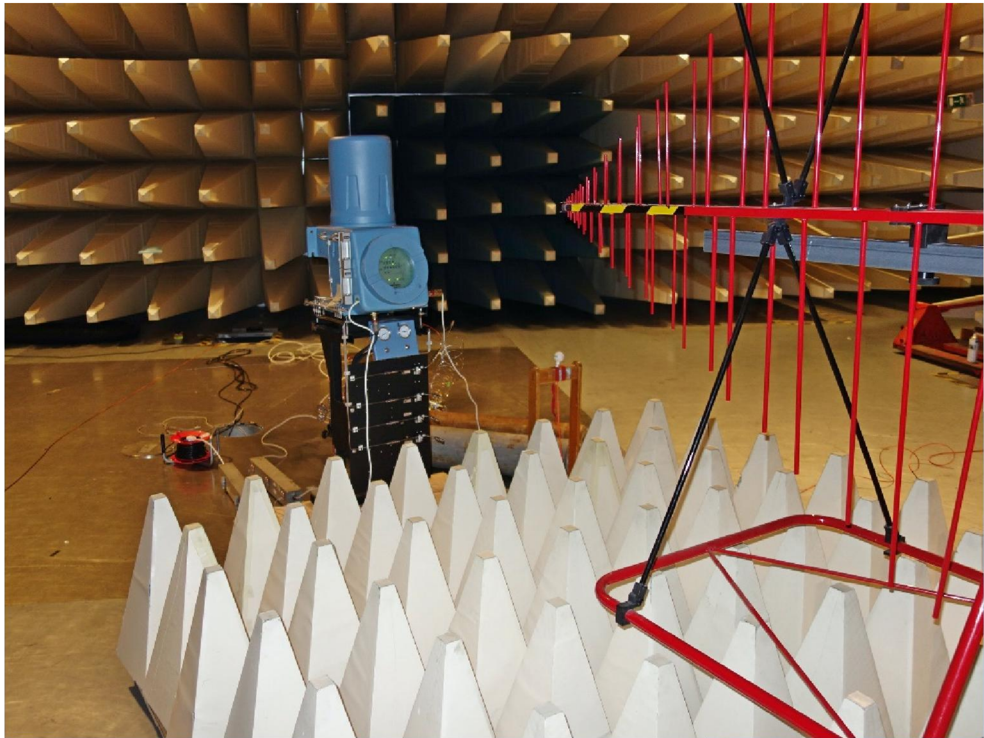
INTERNATIONAL ACTIVITIES

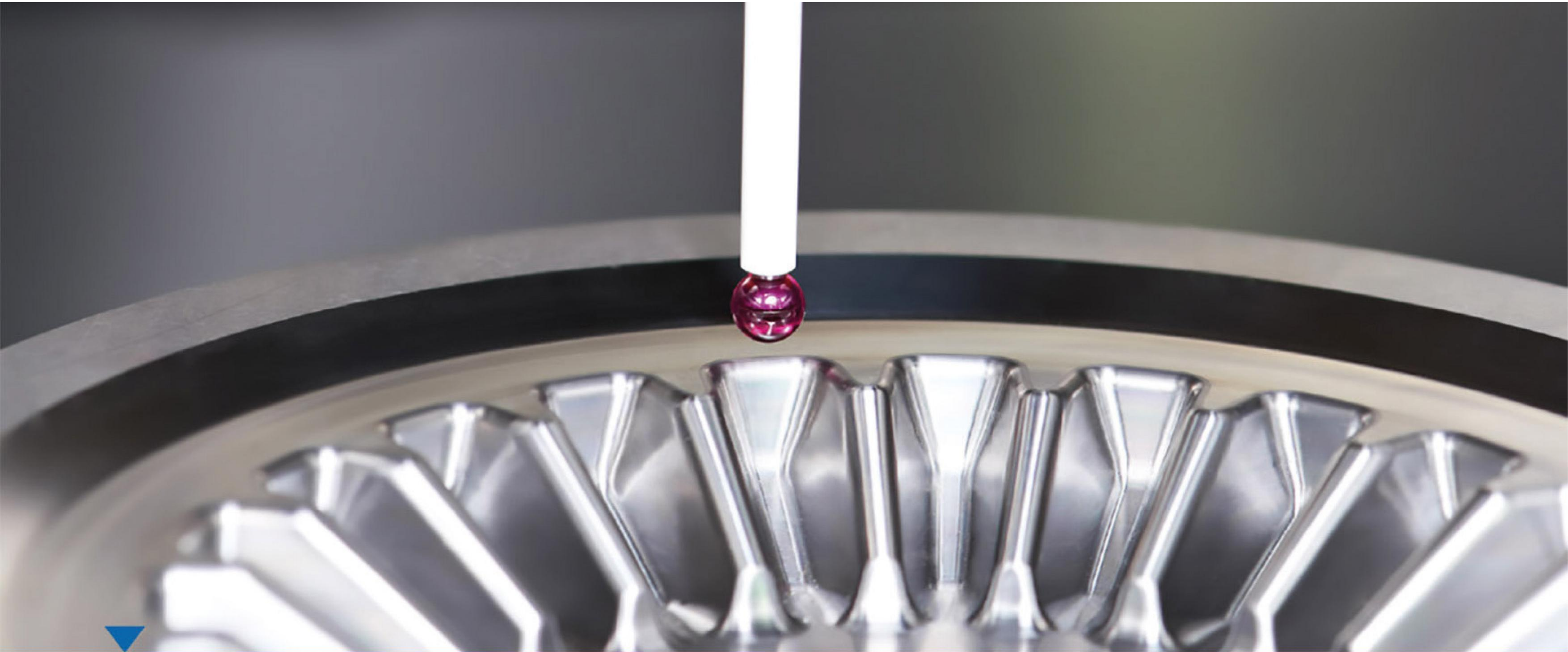
- EMRP project IND 60 EMC Industry
  Improved EMC test methods in industrial environment

- EMPIR project 17NRM02 MeterEMI
  Electromagnetic Interference on Static Electricity Meters

- Interlaboratory comparisons (EMC)
- EMC Measurement of railway applications in Europe
- International projects and training of experts

Testing laboratory





THANK YOU FOR YOUR ATTENTION

CZECH
METROLOGY
INSTITUTE

Okružní 31, 638 00 Brno, Czech Republic, + 420 545 555 111, www.cmi.cz