



## TC-EM Highlights

9<sup>th</sup> EURAMET GA  
Krakow 2-3 June 2015

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Electricity and  
Magnetism

### Outline

- CIPM/MRA
  - ✓ Comparisons
  - ✓ CMCs
- Calibration guides
- R&D activities
  - ✓ Key results
  - ✓ EMPIR calls (2014 & 2015)

10 minutes  
chrono !



## CIPM/MRA: EURAMET TC-EM Comparisons in 2014



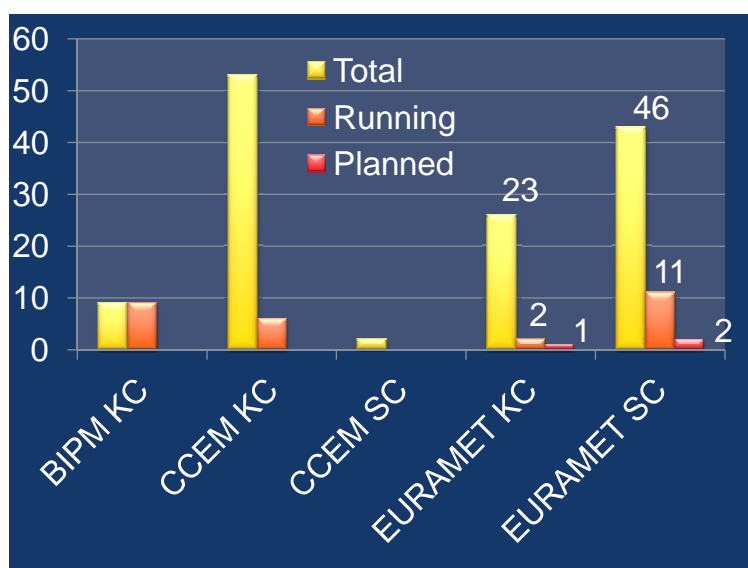
- **5** completed comparisons  
4 SCs + 1 outside BIPM/KCDB
- **17** Running comparisons  
2 KCs + 11 SCs + 4 outside BIPM/ KCDB
- **3** new comparisons in preparation/discussion  
1 KCs + 2 SCs

Id		Pilot	Nb. Part.
K5	Active power, 120 & 240 V, 5 A, 53 Hz; phase 0°, ±60°, ± 90° EURAMET loop in // with CCEM-K5, but slightly delayed (End 2015)	VSL, PTB, METAS	> 4
	Lightning Impulse voltage Starting date: 2015, protocol in preparation	SP	~ 10 (incl non EURAMET)
	S parameter, 1.85 mm-PC coax, up to 67 GHz Within JRP HF-circuits, currently in discussion		4

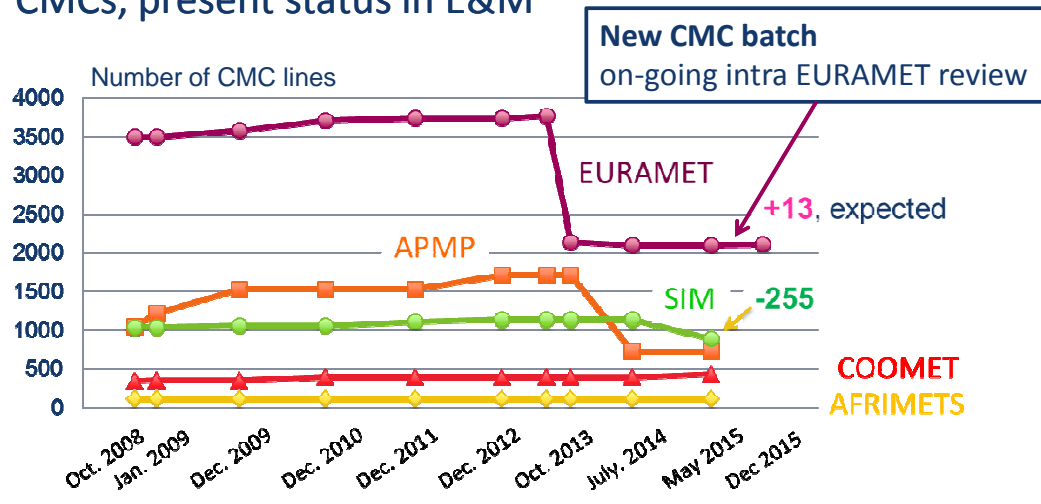
## CIPM/MRA: EURAMET TC-EM Comparisons, an overview



February 2015



## CIPM/MRA: CMCs, present status in E&M



27 May 2015

- ✓ Continued progress in simplifying CMC tables by using matrices
- ✓ Limited growth of nb of CMC lines

RMO	Matrices	Lines	Ratio
AFRIMETS	1	114	0,9%
APMP	318	728	<b>43,7%</b>
COOMET	23	436	5,3%
EURAMET	724	2096	<b>34,5%</b>
SIM	102	882	11,6%
Total	1168	4256	27,4%



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## Calibration guides



n° 7: Calibration of Oscilloscopes (**June 2011**)

n° 9: Measurement/generation of small AC voltage with IVDs (**July 2007**)



*- completely outdated  
- used nowhere*

→ **Today:** removed from the web!

n° 12: Evaluation of VNA (**July 2007**)



*JRP deliverable of SIB62  
(HF-Circuits)  
Date: **End of 2015***

n° 15: Calibration of digital multimeters (**July 2007**)



*Updated version published on **February 2015** !*



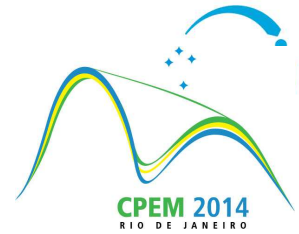
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6

Some key results in 2014 ...

Selected !



## ● CPEM'2014

New Planck constant values, QHE in graphene, pulse driven Josephson array

**but also:** SET current sources, CCC and low current amplifier (ULCA), digital impedance bridge, synchrophasor (PMU), High current and voltage transformer, HF power standard, modelling of connector effects in millimetre band, etc

## ● JRPs finishing in 2014

**EMINDA:** Electromagnetic characterization of materials for industrial applications up to microwave frequencies

**Ultrafast:** Metrology for Ultrafast Electronics and High-Speed Communications

**MetMags:** Metrology for advanced industrial magnetics

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7

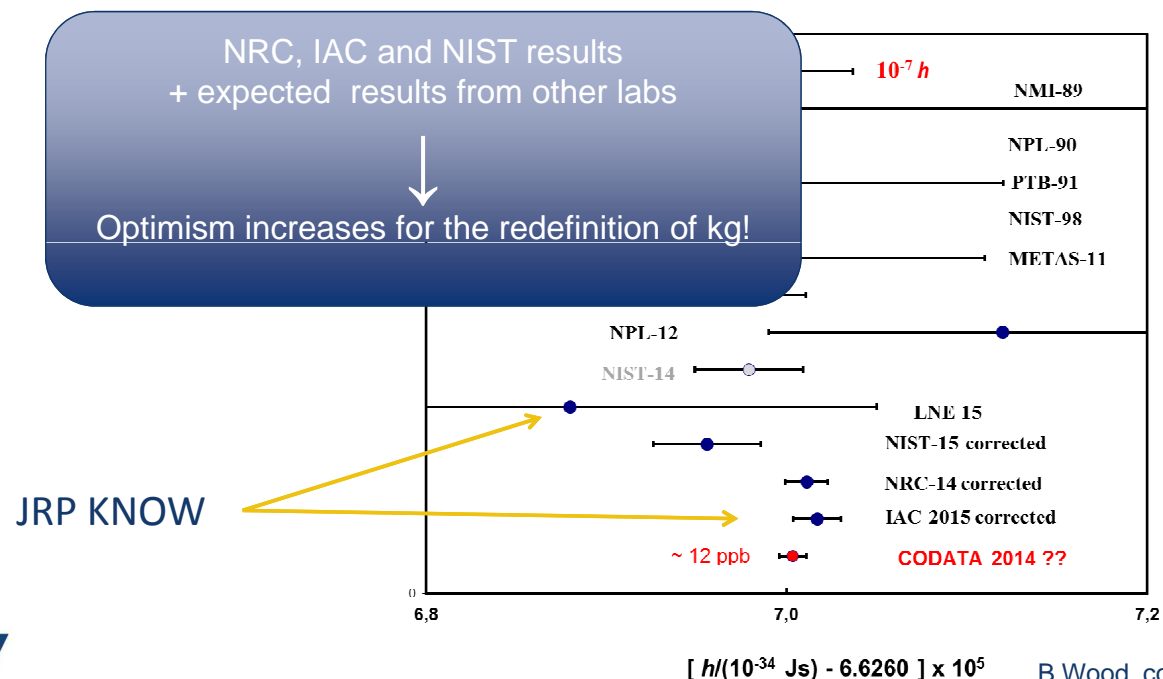


Some highlights in 2014 – SI

in links with TCM



New values of  $h$  from watt balance and silicon sphere (JRP KNOW)



## Some highlights in 2014 - QM



### QHE in graphene (JRP graphohm)

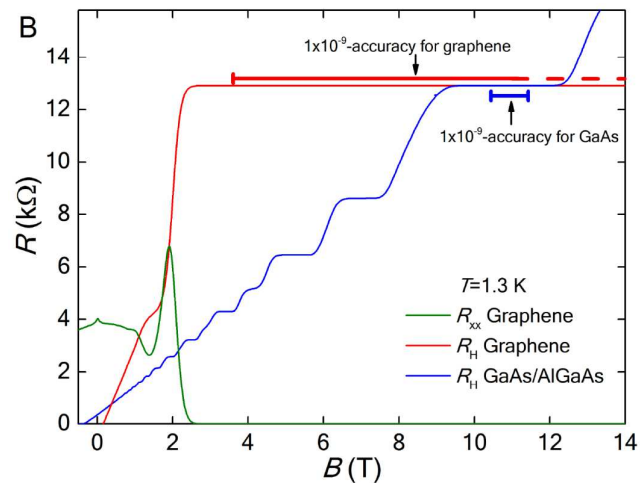
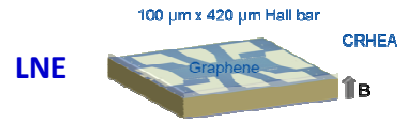
F Schopfer, courtesy

$$(R_{H-g} - R_{H-GaAs})/R_{H-GaAs} = (-0.9 \pm 8.2) \cdot 10^{-11}$$

$B$  from **4** to 8 T

$T = \mathbf{1.3\ K}$

$I$  from 20 to 60  $\mu\text{A}$



Ribeiro-Palau *et al*, condMat



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## Some highlights in 2014 - QM

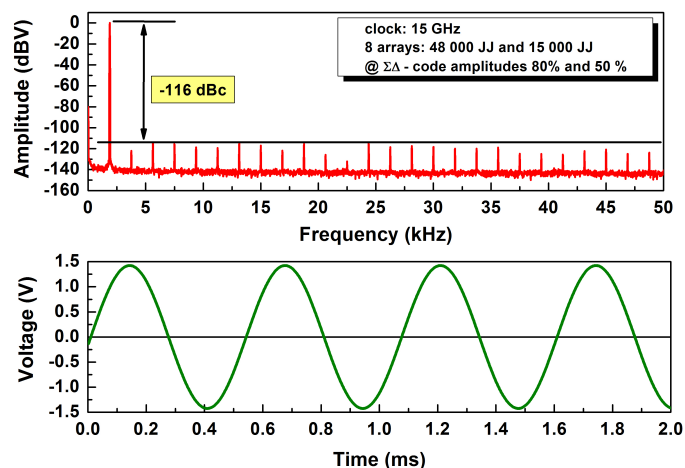


### Pulse driven array (JRP Q-wave)

Pulse-driven Josephson arrays as synthesizer have reached the **1 V level**

R Behr, courtesy

Almost perfect  
synthesizer for arbitrary  
waveforms!



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2011- 2014, Industry

**NPL**, LNE, METAS, PTB, SIQ, AGILENT Austria, MG and REGs

Goals:

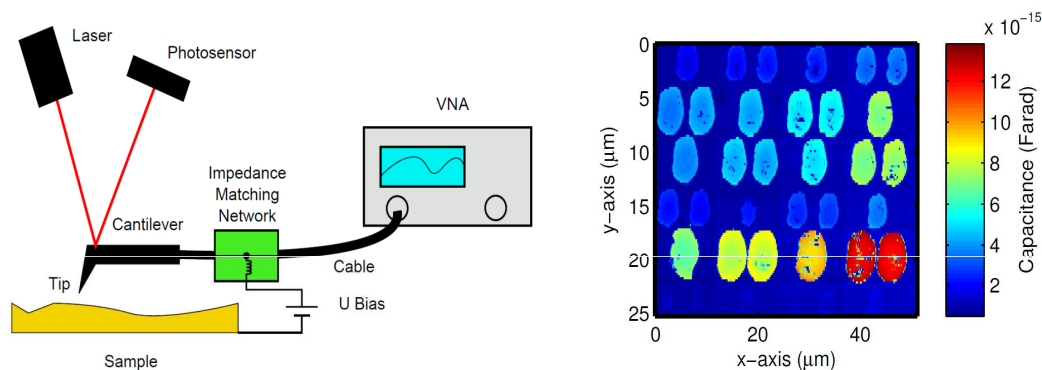
Traceable material measurements over a wide frequency range

- of different EM material parameters (permittivity, permeability, ...)
- for different materials (functional, laminar, thin film, bulk, ...)
- using different techniques (NFSMM, CPW, cavity based, ...)

→ Most objectives reached, some too ambitious

## JRP EMINDA: Results

Nearfield scanning microwave microscope (NFSMM)



Main achievements:

- Two calibration algorithms developed and demonstrated for NFSMM
- Method of Moment program written for tip calculation
- New type of calibration substrate (resistive, based on Si<sub>3</sub>N<sub>4</sub> membrane)
- Uncertainty calculation

## Call 2014

### 4 funded JRPs

#### « Metrology for Industry »

- Metrology for 5G communications
- Metrology for the electrical power industry
- Microwave measurements for planar circuits and components
- Metrology for manufacturing 3D stacked integrated circuits

### 1 funded JRP

#### « Research potential »

Towards the propagation of ac quantum voltage standards

## Call 2015

### Identified submitted PRTs

Call	Provisional Title
<b>Health</b>	
1	Metrology for hyperthermia
2	Metrology for Wireless Body Area Networks
<b>SI</b>	
1	Towards nano scale traceable magnetic field measurements
2	Metrology for electrical scanning probe microscopy
3	Resistance & impedance metrology based on graphene
4	Metrological Application of spectrally pure Josephson-ac-voltages
5	Quantum ampere II
6	HF power measurements and THz
<b>Normative</b>	
1	Pre-normative standardization activities for graphene and 2D atomic materials
2	EMC
3	High voltage
<b>RPot</b>	
1	Traceability of electrolytic conductivity measurements
2	Metrological Performance of Floating Gate Voltage References
3	Digital power measurements



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Thanks a lot  
for your attention!



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