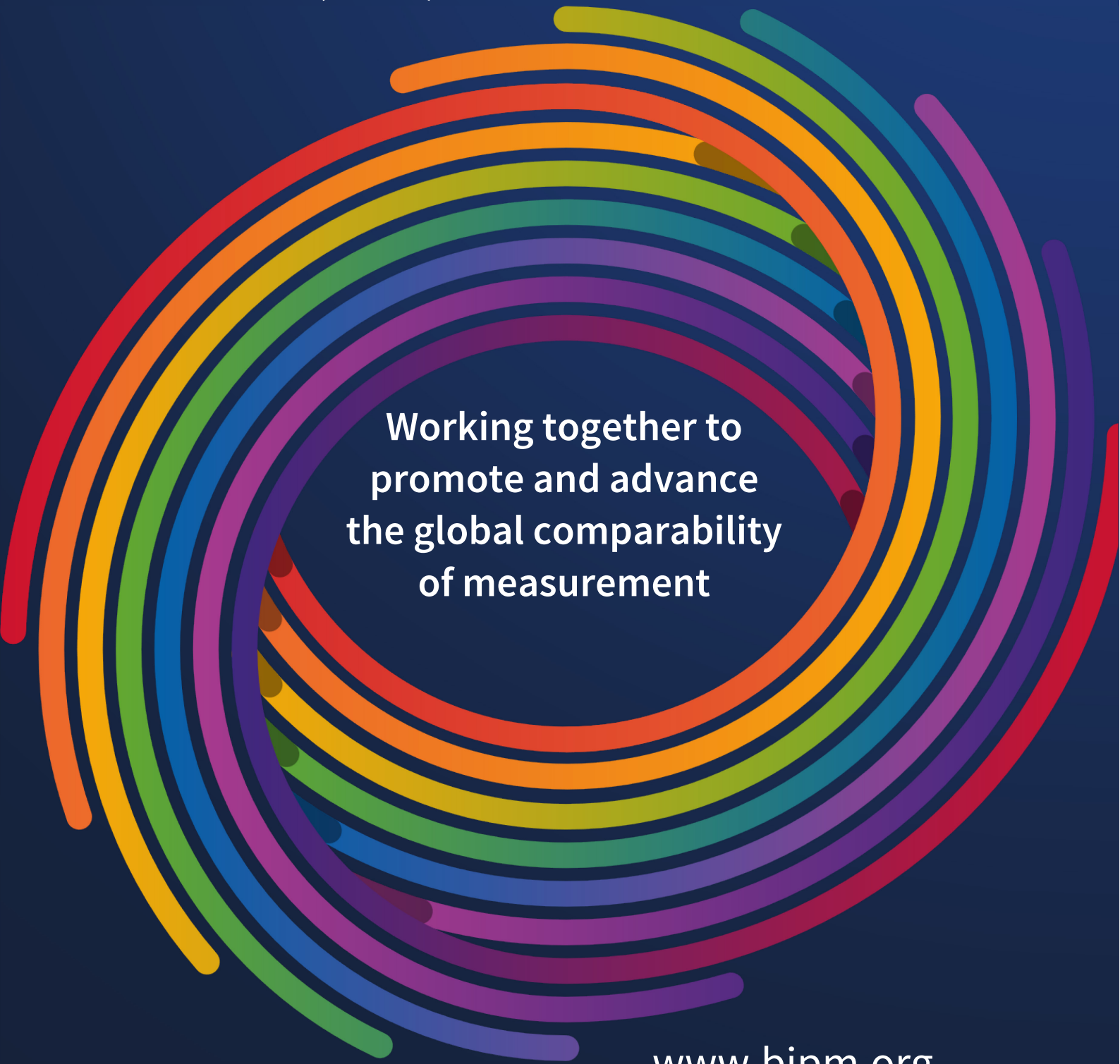
CGPM

CCEM President's Report

27th CGPM (2022)



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Report by the President of the CCEM

Prof. Gert Rietveld, President of the Consultative Committee for Electricity and Magnetism (*Comité consultatif d'électricité et magnétisme, CCEM*) reported on the activities of the CCEM since the 26th meeting of the CGPM (2018).

CCEM Executive summary

The Consultative Committee for Electricity and Magnetism covers a very broad field of metrology with many derived units, over a large range of values and covering a wide frequency range. Until 2018, a significant amount of work was devoted to Kibble balances, in terms of electrical method to realize the kilogram, in support of the planned revision of the SI. Since the 26th CGPM, work focused on further promoting the revised SI and to assure a correct implementation of the revised SI in the EM community on 20 May 2019. The CCEM was pleased to note that the small step changes in the realization of the volt and the ohm (and related derived quantities) caused by implementation of the revised SI have not led to any problems in industry.

In 2020, the CCEM strategy has been completed revised, setting new priorities for the future. These include addressing future challenges for electrical measurement science originating from the development of emerging technologies for example smart electrical grids incorporating renewable energy production, high-frequency communication, electric vehicles and sensor networks. To enhance the impact on global measurement challenges, workshops have been organized with contributions from high-level speakers from industry. Capacity building and further interactions with industry were promoted by starting a series of webinars showcasing the relevance of EM metrology to the wider EM stakeholder community.

Steps have been taken to further increase the impact and the efficiency of the CIPM MRA in the EM area, most notably via supporting the BIPM in developing and implementing the KCDB 2.0, via more strategic planning of comparisons, and the full implementation of a more efficient CMC review process. The BIPM has provided continued and important support to the world-wide comparability of EM measurements, amongst others, via its ongoing key comparison programme.

Scope of the CCEM

The CCEM is responsible for advising the International Committee for Weights and Measures (CIPM) on all matters related to measurement standards for electricity and magnetism, including the EM work programme activities of the BIPM Physical Metrology Department.

The application of electricity is ubiquitous in daily life and electrical metrology covers a broad field involving many quantities and requiring many derived standards. Typical examples are voltage, current, resistance, capacitance, inductance, power, transformer ratio, ac-dc transfer, electrical field strength, magnetic field strength, antenna factors and radiofrequency scattering parameters. In many cases, the quantities span both a very wide range of values (for example nanovolts to megavolts) and frequencies (ranging from dc far into the radiofrequency range), with different techniques required for different ranges.

Due to the vastly different technologies required in the low frequency and the radiofrequency ranges, the detailed technical work of the CCEM is undertaken by two CCEM Working Groups: a low-frequency and a radiofrequency working group (WGLF and GT-RF respectively). A third working group (WGRMO) assures an effective and efficient implementation of the CIPM MRA in the EM community, which is a particularly relevant task given the wide range of CMCs in electromagnetic metrology.

Strategy

In 2019–2020, a completely revised CCEM strategy was developed and approved by the CCEM members, setting new priorities for the future. The strategy was based on the outcomes of the 2017 CCEM workshop on "Future Challenges in Electrical Metrology" and subsequent discussions within the CCEM. These include addressing future challenges for electrical measurement science originating from the development of emerging technologies like smart electrical grids incorporating renewable energy production, high-frequency communication, electric vehicles and sensor networks. Fundamental quantum phenomena underpin the extraordinary accuracy that can be achieved with electrical measurements and the CCEM support to development of novel quantum technologies will continue to have a significant impact on electrical metrology. A general challenge for the CCEM community is the ubiquitous application of electricity and electrical measurements that leads to a large number of electrical quantities, having wide ranges of values and frequencies ranging from dc far into the GHz-range.

The CCEM aims to provide leadership and vision to NMIs and DIs to inform their decisions on measurement science and research activities. To this end, it organizes information exchange through scientific presentations and workshops on emerging technologies with high-level speakers from industry. To further enhance capacity building and interactions with industry, a series of webinars started that showcase the relevance of EM metrology to the wider EM stakeholder community.

The CCEM supports the global comparability of measurements by implementing the CIPM MRA through the organization of key comparisons and coordination of RMO key and supplementary comparisons. It maintains an extensive list of service categories for which CMCs can be submitted. The CCEM seeks actively for ways to further improve the efficiency of comparison organization and CMC review.

An important part of the CCEM's work is to oversee the work programme of the BIPM electricity laboratories. The BIPM comparison services form an integral part of the CCEM comparisons and allow NMIs to uniquely demonstrate their measurement capabilities at the best uncertainty levels. BIPM calibration services provide traceability to a significant number of NMIs without their own primary realizations.

Activities and achievements since the last meeting of the CGPM

Main activities and achievements

Following the major scientific efforts in the years preceding the introduction of the revised SI on progressing electrical methods to realize the kilogram (Kibble balances), the focus of this research has now shifted to supporting the CCM community in advancing implementation of Kibble balances for realizing the kilogram and in extending the use of (simplified) Kibble balances over a wider range of mass. The CCEM was pleased to note that the introduction of the revised SI, and the small step change this introduced in voltage and resistance measurement and derived quantities, has not led to any significant problems in the industrial and wider electrical stakeholder community. Following this success, the two working groups related to this work, the WGSI and WGKG, were closed with particular gratitude to excellent work performed by the chairs of these groups, Dr Ian Robinson, Dr Barry Wood and the late Dr Brian Kibble.

The CCEM also started supporting the CCRI with its expertise of small current measurements with the aim "to guide the introduction of new technologies for the measurement of low electrical current for ionization chambers used in the measurement of radionuclide standards." A joint CCEM-CCRI task group of 18 experts is preparing a 'best practice guide', that will improve traceability in radionuclide metrology and possibly allow for reducing the number of sealed radioactive cells required to check the linearity over a certain range.

A fully-revised CCEM strategy was developed by a task group consisting of the CCEM President, Executive Secretary and WG chairs based on the results of a highly-successful workshop on "Future challenges in electrical metrology" in 2017 and

subsequent discussions in the CCEM. This strategy, setting the direction and priorities of the CCEM for the coming decade, was discussed and adopted by the CCEM members at the 32nd meeting of the CCEM in April 2021.

One of the main aims of the CCEM is to provide leadership and vision to NMIs and DIs to inform their decisions on measurement science and research activities. Scientific presentations providing insight in the state of the art in certain EM areas therefore form an important part of the CCEM meeting agendas. In addition, stimulated by the success of the first strategy-related workshop in 2017, a scientific workshop on "Metrology for radiofrequencies and microwaves (RF&MW)" was held in conjunction with the 31st meeting of the CCEM in March 2019. At this workshop, speakers from industry, universities and NMIs provided overviews of recent challenges in RF&MW metrology related to among others mm-wave wireless communications, implementation of 5G networks, and on-wafer RF characterization of devices for the mobile industry.

To further enhance capacity building and interactions with industry, a series of webinars were started in 2022 that showcase the relevance of EM metrology to the wider EM stakeholder community. These CCEM webinars aim to promote the sharing of knowledge within the wider CCEM community, not only at the high end, but also more basic topics. Compared to presentations at scientific presentations, webinars aim to be more pedagogical and include an introduction to the topic. The first webinar summarized the CCEM strategy and the BIPM work programme and was attended by more than 100 participants from all regions world-wide. The webinars are available on the BIPM YouTube pages.

The effective and efficient implementation of the CIPM MRA is a recurring item on the agenda of the CCEM and its working groups, and in particular of the CCEM WGRMO. Major support has been given to the BIPM in setting up and implementing the KCDB 2.0. The launch of the web-based user platform of the KCDB 2.0 in October 2019 marked a major improvement in the CMC submission and review process, which is particularly relevant for the CCEM community with its more than 4 000 entries (including complex matrices) over 190+ services categories.

Key comparison results are the technical basis of many CMC submissions. After a first series of comparisons following the start of the CIPM MRA, a second round of key comparisons (KCs) is being strategically planned and performed. The KC planning aims to optimize the workload and confidence in international traceability of electro-magnetic quantities world-wide. In several KCs, the workload of coordinating the comparison is shared among several NMIs. The BIPM has performed a first CCEM comparison using a star scheme, where all participating NMIs sent their travelling standard to the BIPM at the same time. This approach required a significant effort by the BIPM as the central laboratory in the star scheme, but at the same time allowed completion of the comparison in 20 months. Because of this major advantage, where possible, this star-scheme approach will be adopted in future CCEM comparisons.

Challenges and difficulties

The Covid-19 pandemic was a major challenge for the CCEM community. It has limited the opportunity for exchange of information and for in-depth discussions during in-person CCEM meetings and the related (highly-appreciated) scientific workshops. At the same time, the increased availability of web meeting facilities has increased interactions within the CCEM working groups and task groups. It also allowed the launch of the CCEM webinars that facilitated increased outreach to the wider EM stakeholder community, including standardization and industry.

A second challenge is to ensure sufficient progress in the key comparisons. Whilst this has already been an attention point in the past due to customs issues or technical problems with the travelling standards for example, the pandemic has further impacted the progress of several CCEM key comparisons, causing delays of up to more than one year. It is expected that the increased use of the star scheme will increase the efficiency of future comparisons and reduce the total lead time.

Outlook in the short and long term

In the coming years, CCEM activities will focus on implementing the renewed CCEM strategy on promoting electrical measurement science, global comparability and improving stakeholder involvement. The latter will include further organization of workshops, expanding the webinar programme, and strengthening links with other international organizations and the wider EM industry, for example in developing foresight exercises.

Continuous attention will be paid to efficient implementation of the CIPM MRA, with particular emphasis on improving the total lead time of key comparisons. The BIPM programme is expected to play an important role in supporting the CCEM community. New BIPM services to the CCEM community are expected to become available in the coming years, covering for example traceability of AC signals exploiting AC quantum voltage standards, and improved traceability in impedance via the calculable capacitor and the (AC) quantum hall effect based on graphene.

On the longer term, the CCEM is expected to increase its contributions to major scientific and technological metrology challenges related to global themes like the energy transition, to extended implementation of quantum standards in industry and to the wider ubiquitous application of electricity and electrical measurements in our societies.

CCEM Data

CCEM set up in 1927 (as the CCE)

President:	Prof. G. Rietveld
Executive Secretary:	Dr M. Stock
Membership:	26 members and two observers
List of CCEM members and observers:	https://www.bipm.org/en/committees/cc/ccem/members
Meetings since the 26th CGPM meeting:	28-29 March 2019, 14-15 April 2021
Full reports of the CCEM meetings:	https://www.bipm.org/en/committees/cc/ccem/publications
Three Working Groups:	https://www.bipm.org/en/committees/cc/ccem – RMO Coordination (WGRMO) – Low-Frequency Quantities (WGLF) – Radiofrequency Quantities (GT-RF)

CCEM Comparison	Completed	In progress	Planned
CCEM key comparisons (and supplementary comparisons)	50	7	7
BIPM comparisons	1	9 (ongoing)	9 (ongoing)
CCEM pilot studies	0	1	2
CMCs	4642 CMCs in 194 service categories registered in the KCDB		