INTERNATIONAL METROLOGY – ENSURING CONSISTENCY WITH OUR TRADING PARTNERS

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1. INTRODUCTION

The National Physical Laboratory is the United Kingdom's national standards laboratory, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science. For more than a century NPL has developed and maintained the nation's primary measurement standards - the heart of an infrastructure designed to ensure accuracy, consistency and innovation in physical measurement, including acoustical measurement.

NPL's main commitments are to support UK industry, but in doing so it needs to maintain its standing internationally. The reasons for this are two-fold. First, it is vital for everyone that primary standards in the UK are consistent with those in other nations and second, greater progress in these areas can be achieved by collaborating internationally, for example through Euromet.

The issue of international consistency became formalised in 1999, when at a meeting in Paris, the director of NPL along with the other thirty-seven Member States of the Metre Convention and representatives of two international organizations signed a Mutual Recognition Arrangement (MRA) for national measurement standards and for calibration and measurement certificates issued by national metrology institutes. The consequence of this is that users of instrumentation can henceforth source traceable calibration services globally. However, the MRA must be underpinned with some technical assurance that the measurement standards and quality of calibration are indeed equivalent.

2. INTERNATIONAL COMMITTEE ON WEIGHTS AND MEASURES (CIPM)

This technical assurance is addressed by the CIPM, which has set up a number of Consultative Committees that bring together the world's experts in their specified fields as advisers on scientific and technical matters.

The Consultative Committee on Acoustics, Ultrasound and Vibration (CCAUV) was formed in 1998, formally recognising the first time the importance of measurement standards in these fields. One of the tasks of CCAUV is the identification, planning and execution of key comparisons of national measurement standards. At its first meeting in 1999 the CCAUV initiated five key comparisons; one in the field of airborne acoustics on the calibration of laboratory standard microphones of type LS1, two in ultrasound and one each in underwater acoustics and vibration.

Results from these exercises establish a reference value for the particular quantity, against which the performance of any individual laboratory can be compared. However it will be necessary to first consider how the metrology is organised worldwide, before appreciating how this can be done.

3. REGIONAL METROLOGY ORGANISATIONS (RMOs)

Even before the formation of CCAUV, national laboratories around the world have cooperated to compare results and collaborate in research. In the European Union the body which fosters this collaboration is known as Euromet. Formed in 1988, Euromet spans all fields of metrology including Acoustics, Ultrasound and Vibration.

The mains aims of Euromet are to

- encourage cooperation in the development of national standards and measuring methods
- optimise the use of resources and services
- improve measurement facilities and making them accessible to all members
- perform comparisons to ensure a better coherence of measurements.

Similar organisations exist in other parts of the world encompassing all the national laboratories, many of which are also represented in CCAUV.

4. DEMONSTRATING EQUIVALENCE IN MEASUREMENT STANDARDS

The CIPM consultative committees and the regional metrology organisations together provide the framework enabling the capability of any two laboratories to be compared. This is achieved through co-ordinated comparisons at two levels. So-called key comparisons within CCAUV are undertaken by a small number (usually 1 but in some circumstances up to 3) of leading laboratories from each RMO. For a given quantity, these leading laboratories then establish a reference value, the benchmark for determining equivalence. The key comparisons are then supplemented by regional comparisons organised in the RMOs. This allows a greater number of laboratories to participate, including laboratories that have taken part in the corresponding key comparison. Using the results of the laboratories that take part in both regional and key comparisons, the results of all participating laboratories can be linked to the key comparison reference value. If this process is then repeated in all RMOs, the results from any two laboratories can be compared without them needing to take part in the same comparison exercise.

Implementing a scheme like this clearly needs some co-ordination and an easy way of accessing the data. This is the responsibility of the International Bureau of Weights and Measures (BIPM). They maintain the web-based key comparison database (KCDB) that contains

- A list of national metrology institutes that are signatories to the MRA.
- A list of CIPM and RMO key comparisons and regional comparisons that are planned or have taken place
- Further information on the comparisons, such as the measurand, participants, results and final reports as they become available.
- The Calibration and Measurement Capabilities (CMCs), The quantities for which calibration and measurements certificates are recognised by participating institutes.

The KCDB is therefore a key resource for worldwide metrology.

5. COMPARISONS IN THE CALIBRATION OF LABORATORY STANDARD MICROPHONES

The KCDB is currently being updated with results from a recently completed key comparison on the calibration of laboratory standard microphones, referred to as CCAUV.A-K1. Twelve national measurement laboratories took part and the NPL piloted the project. Two travelling standard microphones were circulated and the participants reported their results in the frequency range from 125 Hz to 8 kHz. It was a requirement of the project that each participant performed their usual calibration procedure and reported their results in the form they would normally use.

Participant (in order of participation)	Acronym	Country	Country Code	Regional Metrology Organisation
National Physical Laboratory	NPL	United Kingdom	UK	EUROMET
Danish Primary Laboratory for Acoustics	DPLA	Denmark	DK	EUROMET
National Institute of Standards and Technology	NIST	United States	US	SIM
Electrotechnical Laboratory†	ETL	Japan	JP	APMP
Physikalisch-Technische Bundesanstalt	PTB	Germany	DE	EUROMET
Korea Research Institute of Science and Standards	KRISS	Korea	KR	APMP
National Metrology Laboratory of South Africa	CSIR-NML	South Africa	ZA	SADAMET
National Measurement Laboratory	CSIRO	Australia	AU	APMP
National Research Council	NRC	Canada	CA	SIM
Centro Nacional de Metrologia	CENAM	Mexico	MX	SIM
Central Office of Measures	GUM	Poland	PL	EUROMET
All Russian Scientific and Research Institute for Physical-Technical and Radiological Measurement	VNIIFTRI	Russian Federation	RU	COOMET

Table 1. List of participating institutes in CCAUV.A-K1

The key comparison results are summarised in Figure 1. The results are plotted relative to the mean value for the measured sensitivity of the microphone. To generalise the result, this mean value is normalised to 0 dB at each frequency and this becomes the key comparison reference value (KCRV). The results in Figure 1 then illustrate the degree of equivalence of each participant with the KCRV. It also illustrates the degrees of mutual equivalence between individual participants.

The KCDB also considers the measurement uncertainty in all the parameters from the individual measurements to the degrees of equivalence. Clearly, these are vital in assessing whether the observed differences are significant or not. While it is not possible to show all of the data here, it can be noted that at the key frequency of 250 Hz, in all but one case the degrees of equivalence are smaller than the associated uncertainty.

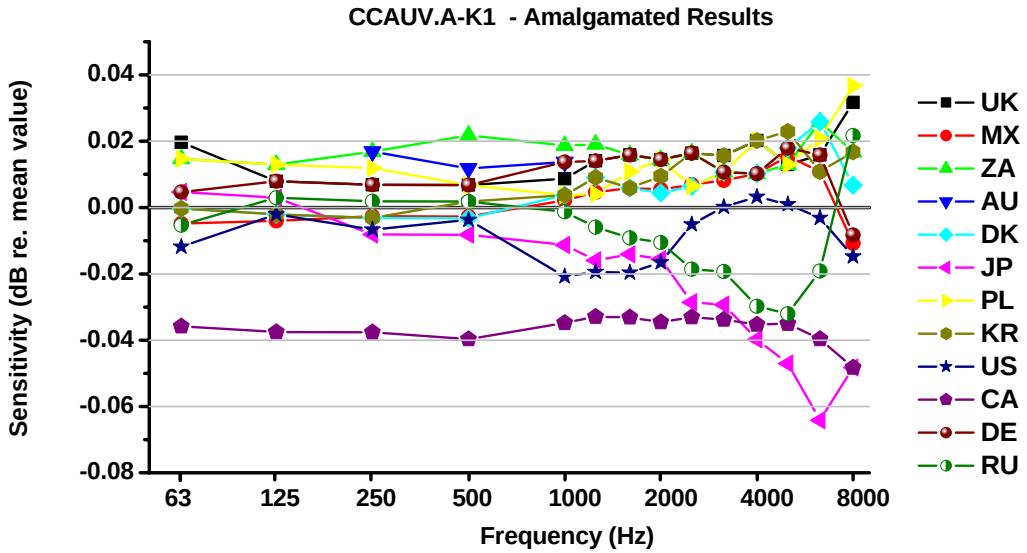

Figure 1. Amalgamated results - deviation of each participant from the arithmetic mean normalised to zero at each frequency.

A full set of results and the final report for CCAUV.A-K1 can be found at http://kcdb.bipm.org/

A further comparison on the calibration of laboratory standard microphones has also been completed in Euromet referred to as EUROMET.AUV.A-K1. Fifteen laboratories participated in this project, including three participants from CCAUV.A-K1. These three laboratories have been used to refer all of the results from the Euromet comparison to the KCRV.

Figure 2 shows the results of the Euromet comparison relative to the KCRV. Comparing the results from each exercise, it is apparent that the spread in results is slightly larger in the regional comparison. This is typical as regional comparisons include results from laboratories with less experience than those that take part in key comparisons. However the uncertainties declared in regional comparisons are usually larger also.

Participant	Acronym	Country	Country Code
National Physical Laboratory	NPL	UK	UK
Physicalische-Technische Bundesanstalt	PTB	Germany	DE
Danish Primary Laboratory for Acoustics	DPLA	Denmark	DK
Czech Metrological Institute	CMI	Czech Rep.	CZ
Institute National de Metrology	INM	France	FR
Telecom Engineering	TE	Finland	FI
Central Office of Measures	GUM	Poland	PL
Instituto Electrotecnico Nazionale	IEN	Italy	IT
Slovenky Metrologicky Ustav	SMU	Slovak Rep.	SV
Orszagos Meresugyi Hivatal	OMH	Hungary	HU
National Metrology Institute	NMI	Turkey	TR
Instituto de Acustica	IA	Spain	SP
Swiss Federal Office of Metrology	OIMF	Switzerland	CH
Swedish National Testing and Research Institute	SP	Sweden	SE
Bundesamt fur Eich-und Vermessungswesen	BEV	Austria	AT

Table 2. List of participating institutes in EUROMET.AUV.A-K1

Other RMOs have completed similar exercises and the database is expanding with the results of these. This is enabling results from a large number of laboratories to be compared – far more than could ever be accommodated in a single comparison exercise.

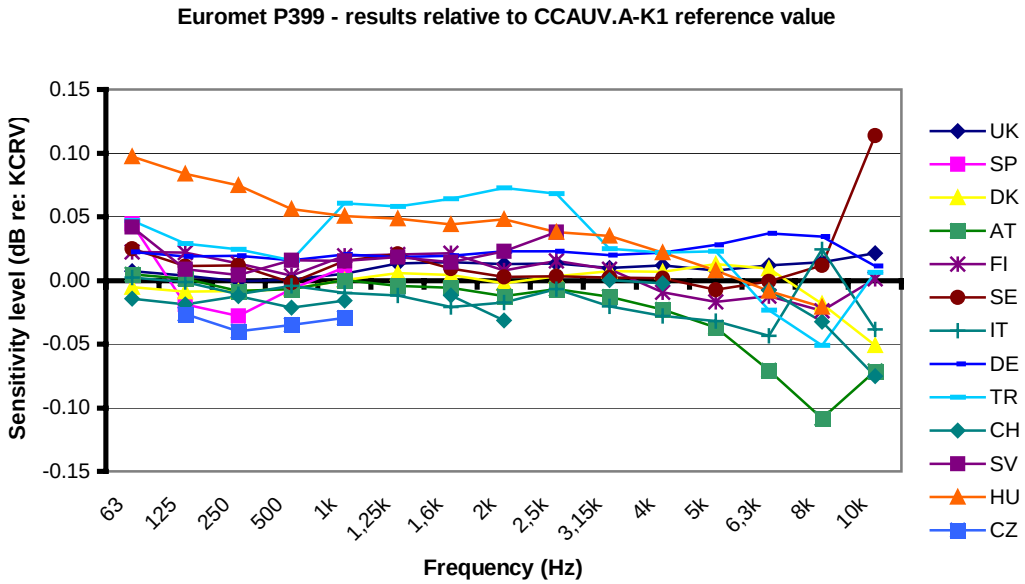

Figure 2. Results from EUROMET.AUV.A-K1. Deviation of each participant from the arithmetic mean normalised to zero at each frequency.

6. CONCLUSIONS

Equivalence in measurement with ones trading partners is a pre-requisite of any national measurement infrastructure. In the past this has been achieved through the voluntary participation in intercomparison organised on an ad-hoc basis. Now that the process has been formalised by the CIPM, the data is becoming much more widely available through the KCDB and any interested party can readily examine the degree of equivalence between a large number of national laboratories.

7. FURTHER INFORMATION

The following web sites are useful sources of further information on international metrology and collaborative research within the national measurement institutes

Euromet: http://www.euromet.org

International Bureau of Weights and Measures: http://www.bipm.fr/enus

Key comparison database: http://kcdb.bipm.org

NPL: http://www.npl.co.uk/international_office

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