TECHNICAL PROTOCOL

Comparison on Calibration of RF Current Monitoring Probe

EURAMET Project No:
EM-1478

TÜBİTAK UME

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Contents

1. Introduction

A RF current monitor probe is commonly utilized in measurements of disturbance currents of cables without making direct conductive contact with the source conductor and without modification of its circuit. The RF current monitor probes must be accurately calibrated according to international standards such as CISPR 16-1-2 [1] and ISO 11452-4 [2]. A calibrated parameter of the RF current monitor probe is transfer impedance which is used at conducted emission and conducted immunity tests. It was decided to organize comparison on calibration of RF current monitoring probe during the EURAMET TCEM SC RFMW including EMC meeting held in Prague in 2017.
The comparison will be carried out in accordance with the CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons [3].

2. Travelling Standard

The travelling standard will be supplied by TÜBİTAK UME. The photo and the general specifications of the travelling standard are presented in Figure1 and Table 1 respectively.

Figure 1. The photo of the travelling standard.

Table 1. The general specifications of the travelling standard

No	Manufacturer/ device	Model	Serial number	General specifications
1	Solar Electronics/ RF Current Monitoring Probe	9123 – 1N	031238	Frequency range: 10 kHz – 500 MHz Window diameter: 32 mm Max. RF current: 40 A Connector type: N (Female)

3. Participant Institutes

The pilot laboratory for this comparison is TÜBİTAK UME (Turkey). The participating laboratories and contact persons with their addresses are presented in Table 2.

Table 2. The information of the participant institutes

Country	Institute	Acronym	Shipping Address	Contact Person
Turkey	TÜBİTAK Ulusal Metroloji Enstitüsü	TÜBİTAK UME **(Pilot laboratory)**	TÜBİTAK Ulusal Metroloji Enstitüsü (UME) TÜBİTAK Gebze Yerleşkesi Barış Mah. Dr. Zeki Acar Cad. No:1 41470 Gebze-Kocaeli, TURKEY	Osman Şen osman.sen@tubitak.gov.tr Tel: +90 262 679 50 00
Austria	Seibersdorf Labor GmbH	Seibersdorf	Seibersdorf Labor GmbH 2444 Seibersdorf, Austria	Alexander Kriz alexander.kriz@seibersdorf-laboratories.at Tel : +43 50 550 2846
Czech Republic	Czech Metrology Institute	CMI	Český metrologický institut Radiová 1136/3 CZ-10200 Praha Czech Republic	Tomáš Pavlíček tpavlicek@cmi.cz Tel: +420 266 020 185
France	LNE Laboratoire national de métrologie et d'essais	LNE	Laboratoire national de métrologie et d'essais 29 avenue Roger Hennequin 78197 Trappes France	Jean-Marie Lerat Jean-Marie.Lerat@lne.fr Tel : +33 (0)1 30 69 11 48
Poland	GUM Central Office of Measures	GUM	GUM Laboratory of Electricity and Magnetism Elektoralna 2 00-139 Warszawa Poland	Marcin Wojciechowski marcin.wojciechowski@gum.gov.pl Tel: +48 22 581 9303
Slovenia	Slovenski Institut za Kakovost in Meroslovje	SIQ	Slovenski Institut za Kakovost in Meroslovje (SIQ) Trzaška cesta 2 SI-1000 Ljubljana SLOVENIA	Borut Pinter borut.pinter@siq.si Tel: +386 (0)1 4778 322
Spain	Instituto Nacional de Técnica Aeroespacial	INTA	Instituto Nacional de Técnica Aeroespacial (INTA) Centro de Metrología y Calibración – Edificio B-15 Ctra. a Ajalvir, p.k. 4,5 28850 Torrejón de Ardoz (Madrid) SPAIN	Manuel Rodríguez rodriguezm@inta.es Tel: +34 91 520 1859

Switzerland	METAS Federal Institute of Metrology	METAS	METAS Laboratory EMC Lindenweg 50 3003 Bern-Wabern Switzerland	Frédéric Pythoud frederic.pythoud@metas.ch Tel: +41 58 387 03 35

4. Time Schedule

The time schedule for the comparison measurements is given in Table 3. The circulation of the travelling standard will be organized to monitor the performance of the travelling standard. Each institute will have one week to carry out the measurements and three weeks to send the travelling standard to next participant. Any deviation in the agreed plan should be approved by the pilot laboratory.

Table 3. The time schedule for the comparison measurements

Participant	Country	Measurement Dates
TÜBİTAK UME (first measurement)	Turkey	02 September 2019 – 06 September 2019
METAS	Switzerland	30 September 2019 – 04 October 2019
LNE	France	21 October 2019 – 25 October 2019
TÜBİTAK UME	Turkey	18 November 2019 – 22 November 2019
CMI	Czech Republic	16 December 2019 – 20 December 2019
SIQ	Slovenia	06 January 2020 – 10 January 2020
TÜBİTAK UME	Turkey	03 February 2020 – 07 February 2020
SEIBERSDORF	Austria	02 March 2020 – 06 March 2020
GUM	Poland	30 March 2020 – 03 April 2020
INTA	Spain	27 April 2020 – 01 May 2020
TÜBİTAK UME (last measurement)	Turkey	25 May 2020 – 29 May 2020

5. Transport Case

The travelling standard will be packed in a strong carrying case, which must be used while the comparison is in progress. The overall dimensions of the case are approximately 20 cm x 12 cm x 17

cm and a total weight of 2 kg. Within institutes, no packaging is required and normal careful handling by qualified personnel will be sufficient. There will be following items in the carrying case.

- RF Current Monitoring Probe.
- Technical protocol of the RF current monitoring probe comparison.

After receipt the carrying case, the participant must check for any damage the items inside of the box. If the travelling standard has any damage due to transportation, this situation must be reported to the pilot laboratory using form presented in Table 4 before beginning the measurement.

When the participated laboratory finish the measurement, the next laboratory and the pilot laboratory shall be informed about shipment using form given in Table 5. If there is no problem for the shipment, all items shall be checked and re-packed into the carrying case and it shall be dispatched to the next laboratory.

6. Transportation of Travelling Standard

Participants will be responsible for arranging transportation to the next participant.

The participants shall inform the pilot laboratory by e-mail when the travelling standard has arrived by filling the following form.

Table 4. Sample form for the information of arrival of the travelling standard

Confirmation Note For Receipt		
Date of Arrival		
NMI		
Name of Responsible Person		
Traveling standard	□ Damaged	□ Not Damaged
Additional Notes:		

The participants shall also inform the next recipient and the pilot institute by e-mail about the shipment of the travelling standard by filling the following form.

Table 5. Sample form for the information of dispatch of the travelling standard

Confirmation Note For Dispatch	
Date of Shipment	
NMI	
Name of Responsible Person	
Shipment Information (company name etc.)	
Additional Notes:	

6.1. Failure of Travelling Standard

In case of any damage or malfunction of the travelling standard, the comparison will be carried out after the travelling standard is repaired.

6.2. Financial aspects

Participants will be responsible for the costs of shipment to the next recipient (transportation and customs formalities) as well as any damage that may occur within its country.

Each participant is also responsible for insurance of the standard from arrival in their institute until arrival in the subsequent institute. The value for insurance purposes can be assumed to be approximately 1000 Euro.

7. Measurement Quantities and Frequency Points

The typical transfer impedance of the RF current probe throughout the frequency range is determined by passing a known RF current (I_C) through the primary test conductor and noting the voltage (V) developed across a conventional 50 Ω load. The transfer impedance in dB form of the RF current monitoring probe is calculated using below the equation.

$$Z_T(\mathrm{dB\Omega}) = 20\log(\frac{\mathrm{V}}{\mathrm{I_C}})$$

The comparison measurements will be carried out at frequencies presented in Table 4. Eventually add more optional frequency points in between (typically 10 / decade)

Table 6. Measurement frequencies for RF current monitoring probe

Measurement Frequencies	Measurement Frequencies (Optional)	Measurement Level (mA)
10 kHz	20 kHz, 30 kHz, 40 kHz, 50 kHz, 60 kHz, 70 kHz, 80 kHz, 90 kHz	3
100 kHz	200 kHz, 300 kHz, 400 kHz, 500 kHz, 600 kHz, 700 kHz, 800 kHz, 900 kHz	3
1 MHz	2 MHz, 3 MHz, 4 MHz, 5 MHz, 6 MHz, 7 MHz, 8 MHz, 9 MHz	3
10 MHz	20 MHz, 30 MHz, 40 MHz, 50 MHz, 60 MHz, 70 MHz, 80 MHz, 90 MHz	3
100 MHz	-	3
200 MHz		3
300 MHz		3
400 MHz		3
500 MHz		3

8. Method of Computation of the Reference Value

The comparison reference value (CRV) for each measurement point will be calculated using the results of all the participant laboratories. The method used will be the weighed mean of the participants not considered as outliers. The determination of outliers will be based on the 3·MAD criterion, which makes use of the median of all participants and of the calculated 'median of absolute deviations' (MAD). The participants whose difference with respect to the median is demonstrated to be more than three times the median of absolute deviations will be considered as outliers, and as such will not be taken into account in the determination of the CRV [4].

9. Measurement Instructions

9.1. Environmental Conditions

- The ambient temperature and humidity must be measured. No corrections will be performed for temperature and humidity effects.
- Preferably, the measurements should be carried out at the ambient conditions given below;

  Temperature : (22 ± 2) °C

  Relative humidity : (45 ± 10) %rh

9.2. Method of Measurement

The transfer impedance of the RF current monitoring probe will be measured by each laboratory used own calibration method.

10. Measurement Uncertainty

The uncertainty of measurement shall be calculated according to the JCGM 100 “Guide to the Expression of Uncertainty in Measurement” [5] for the coverage probability of approximately 95%.

The detailed measurement uncertainty budget is provided for each of the following frequencies:

10 kHz, 100 kHz, 1 MHz, 10 MHz, 100 MHz, 200 MHz, 300 MHz, 400 MHz and 500 MHz.

The example uncertainty budget shown below for the calculation transfer impedance of the RF current monitoring probe may be used by participant laboratories. In the event of other the sources of the uncertainty, the participant laboratories could apply them in the uncertainty table given below.

Uncertainty budget @ the frequency of Hz						
Source of uncertainty	**Type**	**Value**	**Probability distribution**	**k-factor**	**Sensitivity coefficient**	**Standard Uncertainty (dB)**
Mismatch between DUT and VNA	B					
Linearity of VNA	B					
Repeatability	B					
…….	B					
……..	B					
	A					
Total Uncertainty (k=1)						

11. Reporting of Results

The results shall be sent to the pilot institute within three weeks of completing the measurements.

The report shall contain at least:

- Details of participating institute,
- The date of the measurements,
- A brief description of the measurement technique
- The block diagram of the measurement setups
- The measurement devices used in the comparison measurements,
- The complete budget of uncertainty
- The environmental conditions during the measurements,
  - ambient temperature
  - relative humidity
- Results of measurement; The measurement results should be prepared in accordance with Table 7.

Table 7. Measurement results for RF Current Monitoring Probe

Frequency	Z_T (dBΩ)	Measurement Uncertainty (dB) (k=2)	Ambient Temperature (°C)	Ambient Humidity (%rh)
10 kHz				
100 kHz				
1 MHz				
10 MHz				
100 MHz				
200 MHz				
300 MHz				
400 MHz				
500 MHz				

12. Final Report of the Comparison

The pilot laboratory is responsible for the preparation of a comparison report.

The Draft A version of the comparison report will be issued within two months after receiving the participant report by the pilot institute. The Draft A report will be sent to the participants for discussion and approval. The participants will have two weeks to send their comments on the Draft A Report.

After approval, the Draft A report will become the Draft B report. The Draft B report will be approved by all the participants before being released to the appropriate technical committee and EURAMET Secretary for their approval.

13. References

[1] CISP 16 – 1 – 2, Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances, 2014.

[2] ISO 11452 – 4, Component test methods for electrical disturbances from narrowband radiated electromagnetic energy, 2011.

[3] CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons, Ver. 2.1, 2017 (available on the BIPM website: https://www.bipm.org/utils/common/pdf/CC/CCEM/ccem_guidelines.pdf).

[4] W. Bich, M. Cox, T. Estler, L. Nielsen, W. Woeger, “Proposed guidelines for the evaluation of key comparison data”, April 2002. Available at: http://www.bipm.org/cc/CCAUV/Allowed/3/CCAUV02-36.pdf.

[5] Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), JCGM 100, First edition, September 2008 (available on the BIPM website: http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf)