EURAMET Supplementary Comparison Antenna factor for Loop Antennas

Technical Protocol

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1 Introduction

1.1 Historical background

In 2003-2004, the supplementary comparison CCEM.RF-S21.F [1] took place. The aim of the comparison was to determine antenna factors of different kind of antennas:

B. Rohde & Schwarz log-periodic, model HL223: 200 MHz to 1.3 GHz, s/n 834933/018

C. Schaffner Chase bilog, model CBL 6112B: 30 MHz to 2 GHz, s/n 2788

D. Rohde & Schwarz active monopole HFH2-Z1: 9 kHz to 30 MHz, s/n 881060/019

E. EMCO active shielded loop, model 6507: 1 kHz to 30 MHz, s/n 9004-1202

F. EMCO passive shielded loop, model 7604: 20 Hz to 150 kHz, s/n 9904-2465

At that time, they were only 4 participants for the loop antenna comparison:
NMi-VSL, AIST, KRISS and NPL. The frequency points were: 20 Hz, 500 Hz, 10 kHz, 100 kHz, 1 MHz, 30 MHz.

Since 2003, other national metrology institutes like METAS have implemented the calibration capabilities for loop antenna, so that it would be appreciated to perform a comparison again.

1.2 Technical background

A typical loop antenna may cover the frequency range from 10 Hz to 30 MHz. This is a huge frequency range including:

- Alternative Currents (AC) measurement techniques
- Radio-Frequency (RF) measurement techniques

The radiation of the antenna may also be produced using:

- Helmholtz coils
- 3 antenna technique
- TEM cells

A typical broadband antenna calibration is performed by combining different calibration methods.

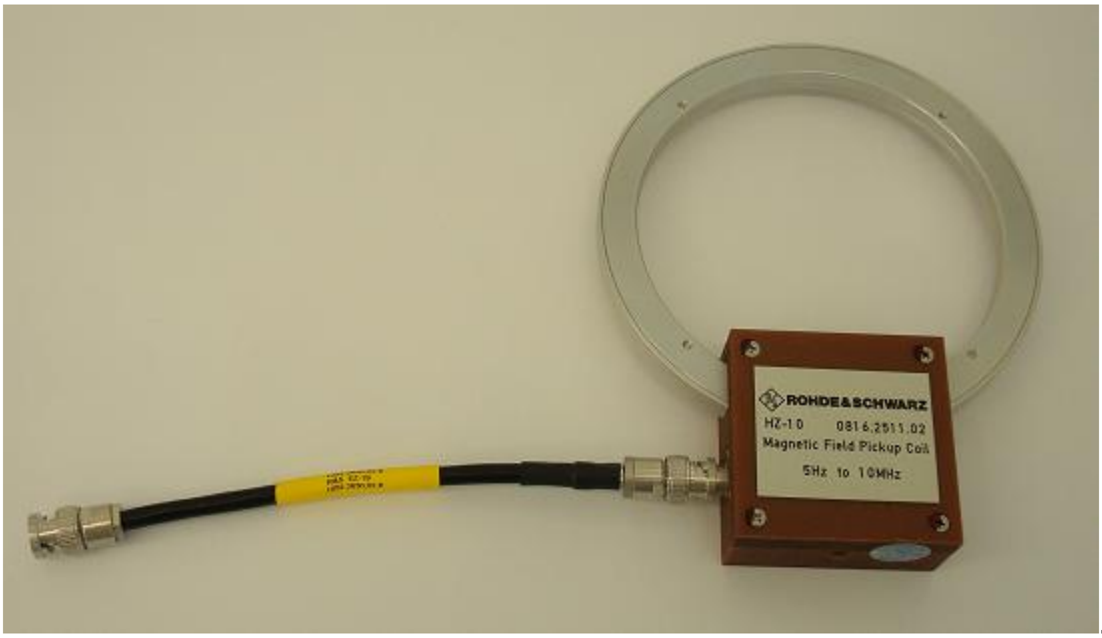
1.3 Motivation

Due to the time span since the last comparison, and to the technical wide spectrum of this magnetic antenna calibration, it is important to start new comparison for European NMIs.

2 Travelling standard

The travelling standard is a loop antenna:

Magnetic Field Pickup Coil, Rohde Schwarz HZ-10, S/N 100149.



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Frequency range: 5 Hz to 10 MHz.
Connector type: BNC.

3 Measurements to be made

3.1 Quantity to be measured:

3.1.1 Quantity 1: the antenna factor

The free field antenna factor AF measured in dB(Siemens/m) which is defined by the ratio of the H-field H (measured in A/m) to output voltage U (measured in V) across a conventional 50 Ω load:

$$AF = 20 \cdot \log_{10}\left(\frac{H}{U}\right)$$

Note: the free field antenna factor is sometimes expressed in dB(pTesla/µV). In this case the following conversion has to be applied:

$$AF_{(pT/\mu V)} = \mu_0 \cdot 10^6 \cdot AF_{(S/m)}$$

or

$$AF_{(dB(pT/\mu V))} = 1.9841 + AF_{(dB(S/m)}$$

where:

- $AF_{(unit)}$ is the free field antenna factor expressed in unit
- $\mu_0 = 4\pi \cdot 10^{-7}\,\mathrm{Vs/Am}$ is the vacuum permeability

3.1.2 Quantity 2: the complex reflection coefficient S11

The complex reflection coefficient S_{11} at the BNC connector should be measured. This coefficient is important for conversions of the free field antenna factor at the reference impedance of 50 Ω, to other reference impedances. However, the S11 measurements will not be part of the comparison itself, but will be displayed informatively in the final report the same way it was performed for the comparison CCEM.RF-S21.F [3].

3.2 Frequency points

The following frequency points are required (9 points per decade):

10 Hz	20 Hz	30 Hz	40 Hz	50 Hz	60 Hz	70 Hz	80 Hz	90 Hz
100 Hz	200 Hz	300 Hz	400 Hz	500 Hz	600 Hz	700 Hz	800 Hz	900 Hz
1 kHz	2 kHz	3 kHz	4 kHz	5 kHz	6 kHz	7 kHz	8 kHz	9 kHz
10 kHz	20 kHz	30 kHz	40 kHz	50 kHz	60 kHz	70 kHz	80 kHz	90 kHz
100 kHz	200 kHz	300 kHz	400 kHz	500 kHz	600 kHz	700 kHz	800 kHz	900 kHz
1 MHz	2 MHz	3 MHz	4 MHz	5 MHz	6 MHz	7 MHz	8 MHz	9 MHz
10 MHz								

3.3 Method of computation of the reference value

The comparison will be performed only on the antenna factor and not on the S11 parameters. The reference value will be computed from the results supplied by the National Metrology Institutes according to reference [2] (procedure A if applicable). Traditional graphical representation of the comparison results, as well as degree of equivalence matrices will be provided at the following frequencies:

- 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz, and 10 MHz.

For the resting frequencies, the results of the participants will be shown in terms of a curve on an X/Y graphics with

- X-axis: frequency
- Y-axis: deviation to Key Comparison Reference Value (KCRV).

4 Organisation

4.1 Pilot Laboratory and support group

The pilot laboratory will be METAS:

Federal Office of Metrology METAS
Frédéric Pythoud
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Lindenweg 50, CH-3003 Bern-Wabern
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The members of the support group:

David Gentle (NPL) david.gentle@npl.co.uk
Dongsheng Zhao (VSL) DZhao@vsl.nl

4.2 Participants

The following participants have expressed their interest in participations in the comparison:

Acronym	**Laboratory**	**Country**	**Contact**
CMI	Český metrologický institut	Czech Republic	Karel Drazil
INRIM	Istituto Nazionale di Ricerca Metrologica	Italy	Luca Callegaro
LNE	Laboratoire national de métrologie et d’essais	France	Djamel Allal
METAS	Federal Office of Metrology	Switzerland	Frédéric Pythoud
VSL	VSL	The Netherlands	Dongsheng Zhao
NPL	National Physical Laboratory	United Kingdom	David Gentle
…	…	…	…
…	…	…	…

4.3 Time Schedule

It is expected that the measurement would start in September of the year 2011.

The pilot laboratory will, in consultation with all participants, prepare a timetable for the comparison. It is expected that each laboratory will have:

- three weeks to perform their measurements.
- one week will be allowed for transportation of the travelling standard between laboratories.

Any deviation to the agreed plan should be agreed by the pilot laboratory.

Each participant's results should be sent to the pilot laboratory within six weeks of the participating laboratory having completed their measurements.

4.4 Comparison pattern

To record the stability of the artefact during the comparison, the pilot laboratory will perform measurements at the beginning and at the end of the comparison, as well as during the comparison by allowing a maximum of three NMI's measurements between stability check.

4.5 Transportation and dispatch

It is expected that each participant covers the freight charges from his location to the next on the list. Each participant is responsible for insurance of the devices from arrival in their laboratory until arrival in the subsequent laboratory. The value for insurance purposes can be assumed to be 800 EUR.

On arrival at the participating laboratory the devices and their packaging should be carefully checked for any damage caused during transit. The pilot laboratory should be informed:

- in case of damage
- on the receipt of the travelling standard
- on the sending of the travelling standard.

5 Measurement instructions

5.1 Measurement method

The choice of the measurement method is left to each NMI, eventually combining different methods.

5.2 Reporting results

The results should be reported in terms of a table with following values:

Frequency	Free Field antenna factor (AF)	Total Standard Uncertainty on AF (k=1)	S11 parameter (Real Part)	S11 parameter (Imaginary Part)	Total Standard Uncertainty on Re[S11] (k=1)	Total Standard Uncertainty on Im[S11] (k=1)
(Hz)	(dB(S/m))	(dB)	()	()	()	()
10						
20						
30						
…						
10'000'000						

For that purpose, an Excel template will be provided.

5.3 Uncertainty of measurement

The detailed measurement uncertainty budget is provided for each of the following frequencies: 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz, and 10 MHz.

The uncertainty budget may be summarized in a table (one for each frequency) as follows (The entries may strongly depend on the measurement technique).:

Uncertainty budget @ the frequency of x Hz						
Source of uncertainty	**Type**	**Value**	**Probability distribution**	**k-factor**	**Sensitivity coefficient**	**Standard Uncertainty (dB)**
Mismatch uncertainty at DUT	B	x (dB)	U-shape	1.41	…	…
Mismatch uncertainty at the reference device	B	y (m)	U-shape	1.41	…	…
Linearity of receiver	A					
…	…					
Field Homogeneity	…					
Repeatability	A					
Total Uncertainty (k=1)						

Due to the use of different measurement techniques, the tables may be differ from one frequency to the other one.

5.4 Measurement report

The report submitted by every participant should include the following information:

- Date of calibration
- Laboratory temperature
- Description of calibration method(s)
- Description of the used measuring equipment
- Final measurement results (using the Excel template provided by the pilot laboratory)
- The detailed measurement uncertainty budget for each of the frequency: 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz, and 10 MHz.

All results should be supplied in electronic form and in English.

6 Final Report

Within 3 months of the final measurements being made by the pilot laboratory, a Draft A Report will be prepared. This report will include a summary of the measurement techniques employed by each participating laboratory, together with their tabulated measurement values with uncertainties. This report will be circulated to all participants for comment.

The revised version of this report (Draft B report), following these comments, will be approved by all the participants before being released to the appropriate technical committee and EUROMET Secretary for their approval.

7 Financial aspects

There is no founding for this project. The costs (time and sending cost) are at charge of each participant.

8 References

[1] CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Attached, Supplementary and Pilot Comparisons, March 21, 2007. http://www.bipm.org/utils/common/pdf/ccem_guidelines.pdf.

[2] 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.

[3] D. A. Knight, M. J. Alexander, "Supplementary comparison: CCEM.RF-S21.F: Final Report", October 2005. http://www.bipm.org/utils/common/pdf/final_reports/EM/RF/S21/CCEM.RF-S21.F.pdf.