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Bi-lateral comparison of LS1P microphone calibration between INTI and INMETRO

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Abstract

In 1997-2000, Instituto Nacional de Tecnología Industrial - INTI (the National Metrology Institute of Argentina) and Instituto Nacional de Metrologia, Qualidade e Tecnologia - INMETRO (the National Metrology Institute of Brazil) participated in a comparison of microphone calibration within the Inter-American Metrology System - SIM called SIM.AUV.A-K1. However, since that time no other comparison was performed within SIM. Therefore, it was agreed between INTI and INMETRO that a new comparison of microphone calibration could be performed between these institutes with the aim to keep the support to the pressure-field sensitivity level. One 1-inch laboratory standard microphone designed for pressure-field (LS1P microphone) was chosen from the pilot laboratory (INTI) since its known stability and calibration history and once it was returned to the pilot laboratory it was recalibrated to certify its stability after travels. Each laboratory used its own procedure for the measurement of sensitivity level and the international standard IEC 61094-2 (1992) guidelines were followed. The institutes’ results were collected throughout the project and were calculated the module of normalized error which are all less than 1, i.e. the results are satisfactory.

Keywords: comparison, microphone, calibration
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1. Introduction

The Inter-American Metrology System (SIM) resulted from a broad agreement among national metrology organization from all thirty-four member nations of the Organization of American States. Created to promote international, particularly Inter-American, and regional cooperation in metrology, SIM is committed to the implementation of a Global Measurement System within the Americas, in which all users can have confidence [1].

In 1997, SIM conducted a comparison of one inch laboratory standard microphone calibration called SIM.AUV.A-K1 with the participation of five National Metrology Institutes (NMIs): NIST from United States of America, CENAM from Mexico, INMETRO from Brazil, INTI from Argentina and INMS from Canadian which was the pilot laboratory [2, 3].

However, since that time, no other comparison was performed within SIM. Therefore, it was agreed between INTI and INMETRO a new comparison could be performed between these two institutes. On September 2014, a bi-lateral comparison was prepared and a calibration protocol was agreed to be followed. This paper presents that bi-lateral comparison.

2. Participants

The participating NMIs were INTI (Instituto Nacional de Tecnología Industrial) and INMETRO (Instituto Nacional de Metrología, Qualidade e Tecnologia) and INTI was the pilot laboratory.

3. Transfer standard

One 1-inch laboratory standard microphone designed for pressure-field (LS1P microphone) was chosen from the pilot laboratory since its known stability and calibration history. The stability was measured since more than 30 years at INTI and is greater than manufacturer’s datasheet specification. That microphone travels from Buenos Aires to Rio de Janeiro on October 2014, was measured by INMETRO and returned on February 2015. Once it arrived again at INTI it was re-calibrated to certify its stability after travel stress. This deviation from the earlier measurement was less than the Calibration and Measurement Capabilities (CMC) [4] declared by INTI at BIPM (International Bureau of Weights and Measures) database.

4. Protocol

All measurement technical specifications were specified and agreed before the comparison begins. The standard circulated was a LS1P microphone, the calibration method used was the reciprocity technique according to the international standard IEC 61094-2:1992 [5] and the measurement were compared using the module of normalized error according to [6]:

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where $M_{\text{INMETRO}}$ are the measurements reported by INMETRO, $M_{\text{INTI}}$ are the measurements reported by INTI, $U_{\text{INMETRO}}$ are the expanded uncertainty of measurements reported by INMETRO and $U_{\text{INTI}}$ are the expanded uncertainty of measurements reported by INTI. The performance of both participants will be considered satisfactory when $|E_n| \leq 1$ [7].

Each NMI followed its own procedure. Table 1 shows the proposed ranges of measurements.

### Table 1: Proposed ranges of measurements.

<table>
<thead>
<tr>
<th>Sensitivity Level in the Frequency Range of…</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5 Hz – 8 kHz (1/1-octave)</td>
<td>Mandatory</td>
</tr>
<tr>
<td>20 Hz – 10 kHz (1/3-octave)</td>
<td>Optional</td>
</tr>
</tbody>
</table>

#### 5. Laboratory methods

INTI follows its own technical procedure [8] (PEA08/Jun.14) that, essentially, uses a reciprocity calibration apparatus combined with a sine generator, two band pass filters and a voltmeter. INTI used only one 3 cc nominal volume plane wave coupler. The dimensions of the plane wave coupler and the front cavity depth of the microphone were measured at INTI. The measured open-circuit sensitivity levels of the microphone were corrected for reference ambient conditions (temperature, humidity and barometric pressure).

INMETRO follows its own technical procedure [9] that, essentially, uses an automated system composed of a reciprocity calibration apparatus combined with a sine generator, a band pass filters and a multimeter. INMETRO used two plane wave couplers, one 3 cc and other 5 cc nominal volumes. The dimensions of the plane wave coupler and the front cavity depth of the microphones were measured at INMETRO. The measured open-circuit sensitivity levels of the microphones were corrected for reference conditions.

#### 6. Measurements results

INTI participated and measured only on mandatory frequencies. INMETRO participated and measured on all frequency range specified in the technical protocol. The calibration data for mandatory frequencies extracted from each calibration report of the same microphone is resumed in Table 2 [10]:

\[ |E_n| = \frac{|M_{\text{INMETRO}} - M_{\text{INTI}}|}{\sqrt{U_{\text{INMETRO}}^2 + U_{\text{INTI}}^2}} \] 

(1)
Table 2: Informed sensitivities extracted from calibration reports.

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>31.62</th>
<th>63.1</th>
<th>125.89</th>
<th>251.19</th>
<th>501.19</th>
<th>1000</th>
<th>1995.3</th>
<th>3981.1</th>
<th>7943.3</th>
</tr>
</thead>
</table>

*dB re 1 V/Pa

The open-circuit sensitivity stability was studied by the pilot laboratory to consider travel stress. The difference between measured values after and before the travel Buenos Aires – Rio de Janeiro – Buenos Aires (Table 3) was within INTI’s declared uncertainties [4] as expected.

Table 3: Differences between the sensitivities after and before the microphone travels.

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>31.62</th>
<th>63.1</th>
<th>125.89</th>
<th>251.19</th>
<th>501.19</th>
<th>1000</th>
<th>1995.3</th>
<th>3981.1</th>
<th>7943.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference [dB]*</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*dB re 1 V/Pa

The expanded uncertainties declared by each institute are summarized in the Table 4:

Table 4: Measurements uncertainties in dB (k = 2, \( \nu_{eff} = 95\% \)).

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>31.62</th>
<th>63.1</th>
<th>125.89</th>
<th>251.19</th>
<th>501.19</th>
<th>1000</th>
<th>1995.3</th>
<th>3981.1</th>
<th>7943.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( U_{INTI} ) [dB]*</td>
<td>0.07**</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>( U_{INMETRO} ) [dB]*</td>
<td>0.07</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.07</td>
<td>0.11</td>
<td></td>
</tr>
</tbody>
</table>

*dB re 1 V/Pa; **This value is not declared at INTI’s BIPM appendix C database.
The acceptance criterion established in the measurement protocol by both laboratories was that the module of normalized error should be equal or less than 1, for all the frequency range. Table 5 and Figure 1 show the calculated $|E_n|$ values for each frequency.

Table 5: Calculated $|E_n|$ values.

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>31.62</th>
<th>63.1</th>
<th>125.89</th>
<th>251.19</th>
<th>501.19</th>
<th>1000</th>
<th>1995.3</th>
<th>3981.1</th>
<th>7943.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>E_n</td>
<td>$</td>
<td>0.20</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.28</td>
<td>0.14</td>
<td>0.14</td>
</tr>
</tbody>
</table>

As an additional analysis, Figure 2 shows the difference between the sensitivities reported by INTI and INMETRO. The bars error are a quadratic combination of both institutes declared uncertainties.
Figure 2: Difference between the sensitivities reported by INTI and INMETRO.

7. Conclusions

The values of $|E_n|$ for all frequencies were less than 1, so the performances of both participants are considered satisfactory as was proposed on the technical protocol.

The results of the comparison are in general quite satisfactory. The result for 31.5 Hz shows very little difference between INTI and INMETRO informed values, despite not being a declared value on INTI’s CMC’s BIPM database. All other differences seem to be within declared CMC’s uncertainties values. At high frequencies (8000 Hz) the differences between INTI and INMETRO are only covered by the quadratic combination of both declared uncertainties. However the values were accepted for its $|E_n|$ criteria.

Both institutes agreed to carry out a new comparison on microphones calibration between more NMI within SIM.

8. References


