

## LOW FREQUENCY MAGNETIC FLUX DENSITY METER CALIBRATION

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**Summary:** This paper shows the basic grounds for meter calibration services of magnetic flux density at low frequency, made available by the Instituto Nacional de Metrologia, Qualidade e Tecnologia (National Institute of Metrology, Quality and Technology) – Inmetro / Brazil.

**Key words:** calibration, magnetic flux, Helmholtz coil, meters.

### 1. INTRODUCTION

The technical Brazilian standard ABNT NBR 15415-2006 establishes the limits for the exposure of humans to alternate magnetic fields generated by transmission and distribution lines by electric devices.

The National Electric Energy Agency (ANEEL, as per its acronym in Portuguese), based on this Standard, established through two regulatory resolutions (Regulatory Resolution No. 398/2010 dated 03/23/2010 and Regulatory Resolution No. 413/2010 dated 11/03/2010) the obligation to perform periodic monitoring in localities where people that have to be exposed to field intensities that are over the allowed limits, under the understanding that when these limits that are over what is allowed could result in eventual risks to people's health, and that they could produce discomfort and place in jeopardy peoples' safety.

According to these resolutions, the Brazilian electricity concessionaries have been forced to perform electric field (EF) and magnetic field (MF) measurements in their lines and substations in order to verify their status within the limits established by the World Health Organization / International Committee on Non-Ionization Radiation Protection (WHO / ICNIRP)

In order to perform those measurements, resolutions determine that the electric and magnetic field metering instruments must have a calibration certificate issued by a competent entity, or by a specialized laboratory or research

center - the inclusion of specialized laboratories or research centers is evident in Regulatory Resolution No. 413/2010 and it was necessary, given the difficulty shown (i.e. the non-existence of accredited laboratories in Brazil that perform such calibrations).

Considering that in Brazil there was no line of competence foreseen by ABNT NBR ISO/IEC 17025, laboratories with the established profile, the Inmetro through Electrical Metrology Division (Diele, as per its acronym in Portuguese) has been empowering to be forerunner in the country to service this significant demand, since the compulsory subject matter would represent a sudden flow short-term needs taking into consideration demands and deadlines to present Conformance Reports.

Lamce (the Metrology Laboratory in Electric and Magnetic Fields at Low Frequency) was created within this scope. This laboratory is linked to the Inmetro/ Diele, and it is the laboratory of reference for the Scientific and Industrial Metrology Board (Dimci, as per its acronym in Portuguese) of Inmetro. It is responsible for safeguarding, maintaining and conducting the Système International d'Unités (SI) of electric and magnetic fields in the country and for spreading these quantities to all the laboratories that form part of the Brazilian Calibration Network (RBC, as per its acronym in Portuguese), electric power manufacturers and concessionaries, thus assuring national traceability.

In this respect, Lamce acts as a strategic decentralization and strengthening instrument of basic infrastructure services in terms of quality and productivity, understanding the demand of the calibration laboratories that have been accredited to perform calibration.

On facing the uncertainties of possible adverse effects on health produced by magnetic fields, and of the questionings and concerns of the electric and industrial area employees regarding their working environment, it is necessary to conduct a discerning evaluation of these levels in the electric facilities that operate with voltages equal or greater than 138 kV, because, the aforementioned effect of those fields can compromise the health, well-living and safety of these workers.

Anticipating, recognizing, validating and controlling these risks has been an on-going concern of this laboratory whose activities, in addition to the calibration of magnetic fields in low frequency (which is the subject matter of this article) will be understood to be as performing EF and MF metering services in facilities, such as: transmission lines, substations, factories and works environments, etc.

The monitored quantity for the magnetic field limit is the magnetic flow density, also known as magnetic induction, whose unit in the International System is Tesla (T), but the Gauss unit (G, equal to  $10^{-4}$  T) and also used in many cases.

Under the context of the new Brazilian requirements for the limits and monitoring of people's exposure to low frequency magnetic fields, Inmetro, through Diele, implemented an initial structure to generate magnetic fields tracked to their own current patterns and instruments calibrated in other countries.

The reference magnetic field is produced by a Helmholtz Coil. An adjustable AC source and a current metering system (8 ½ digits digital multimeter plus shunt) controls the current through the coils and hence, the intensity of the magnetic

The traceability of the magnetic field is assured by the National Measurement Institute (NMI) of Australia and the traceability of the multimeters and shunt resistance by Inmetro's own laboratories.

## 2. METHODS

Although a single coil can be used to generate a reference magnetic field, the group of two identical coils, parallel and with a common axis, commonly known as the Helmholtz Coil, has a clear advantage, as can be seen in the paragraphs below.

Figure 1 shows the basic layout for a pair of square format coils. It is assumed that the same current circulates through both coils in adequate directions, so that the magnetic flow density in any point B (x, y, and z) is given by the sum of the flow densities of each coil.

The theoretic value of the magnetic flux density can be determined with the use of formulas given in literature for an ideal current square path.

The graph shown in Figure 2 shows the variance of the magnetic flow distance along the x axis according to the function of the origin distance for the pair of coils and for a simple coil (both with dimensions of the existing coils in the Inmetro Electricity Division Laboratory).

The values of the distances are percentages relative to half the distance between coils (e) and the origins are the symmetry center (O) for the pair of coils and center (O') for

the single coil. The magnetic flux density values are relative to the values in those points

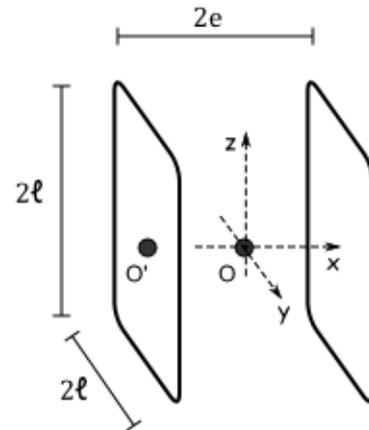


Fig 1 Basic lay-out for a pair of coils

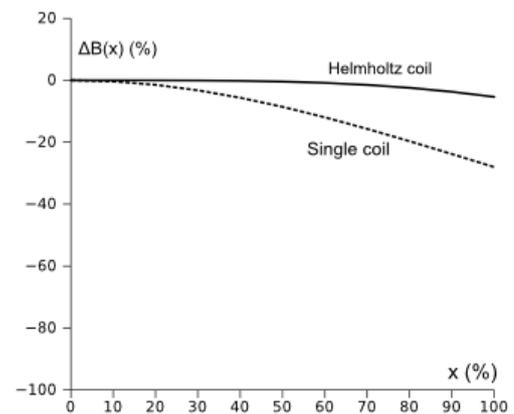


Fig 2 Comparison of a simple coil and with the Helmholtz coil

The curves presented clearly show that the Helmholtz set has a superior uniformity than the one of a simple coil. It can also be demonstrated that there is a similar behavior for the parallel axis (x) in the proximate area. Since the magnetic flux densities along the y and z axis of both coils mutually cancel each other, it can be said that a Helmholtz coil produces a magnetic field that is close to the uniform one, in a localized volume in its symmetry center, if the distance between the coils are equal to an optimum value.

This uniformity is a decisive factor for metrological purposes and, since it can be calculated, the choice of a Helmholtz coil for a given instrument is a determined exactness and a simple task.

Similar results can be obtained for circular coils, but the uniformity volume is somewhat greater for square coils having the same overall dimensions.

Figure 3 shows the calibration method of magnetic flux density meters in Inmetro / Diele.

A sinusoidal signal in the desired frequency (usually 50/60 Hz) is produced by a function generator. That signal is the entrance for a special source that works as a linear power amplifier.

The shunt and the digital voltmeter (DVM1) form the measuring system for the current through the Helmholtz coil set for the current, through the Helmholtz coil.

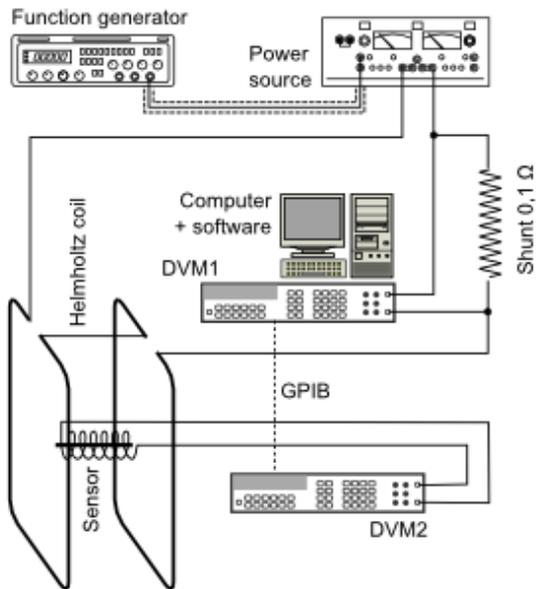


Fig 3 Basic calibration lay-out

The sensor element of the instrument under calibration is placed in the center of symmetry of a couple of coils, in the alignment of a uniform magnetic field. The sensor's output voltage is measured by a second digital voltmeter (DVM2).

The readings of both DVMs are taken simultaneously by means of the GPIB bus and sampling software, in order to minimize the effects of the feeding voltage fluctuations.

The magnetic field generated by a Helmholtz coil is a function of the circulating current and its physical properties.

Consequently, the field inside of the uniform volume can be used as a pattern for the device under calibration.

If the instrument does not allow the measurement of the sensor's voltage, visual readings from its display are taken, with the correspondent loss of accuracy.

### 3. CONCLUSION

The Inmetro Electricity Division with this initial structure can calibrate magnetic flux density meters within the range from 1 to 200  $\mu\text{T}$  (10 to 2000 mG), 60 Hz frequency and expanded uncertainty close to 4%.

Improvements are foreseen for the near future, with the implementation of a primary pattern in order to reduce uncertainties, as well calibration at 50 Hz, ample value ranges and calibration along three axes.

Besides guaranteeing the traceability of the laboratories belonging to the Brazilian calibration network (the main focus) Inmetro will perform measurements/ validations of the electric and magnetic fields seeking to verify:

- Occupational exposure - in facilities such as: laboratories, transmission lines (measurements at ground level and in hot lines), substations, plants, and
- Exposure of the public in general - in facilities such as: offices, the proximity of lines and substations (areas within the limit of safety fences or in the limit of right of way) as well as the fields produced by appliances.

Those measurements can be used to guarantee conformity with the current exposure limits recommended by the ABNT NBR 15415-2006 Standard or by any other future limits that were to be adopted. It will also contribute to improve the employees' health and safety and the population in general.

### 4. REFERENCES

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