European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-r01**
Version: 1.0

Title: A European infrastructure for low magnetic field metrology

Abstract

Measurements in the low magnetic field range, from 10 µT to 10 mT, are much in demand due to recent developments in key areas such as electric mobility, the medical sector, safety and prospecting for ferromagnetic objects. However, only very few European NMIs have the required capabilities to perform traceable measurements in the low magnetic field range. Consequently, the adoption of novel technologies and materials is hindered by the lack of pan-European metrological expertise in this area. Therefore, proposals addressing this SRT should advance capabilities, through the development of a European metrological infrastructure, in order to support the new technologies, markets and applications that rely on low magnetic field measurements.

Keywords

Capacity building, coils, compensation coils, low magnetic field, metrology infrastructure, nuclear magnetic resonance (NMR), primary standard, secondary standard, smart specialisation, traceability

Background to the Metrological Challenges

Low-intensity magnetic field measurements need to be performed in many sectors: 1) they are needed in healthcare and environmental monitoring, where low exposure levels need to be assessed for long periods using calibrated sensors; 2) in biomedicine, where the weak magnetic signals generated by neuronal activity in the human body need to be reliably measured for diagnostic applications; 3) in environmental and industrial detection, where low-intensity static magnetic fields are required for non-invasive and non-destructive testing; 4) in quantum computing and sensing, where new measurement capabilities need to be developed at extremely high and extremely low magnetic field strengths; 5) in new classes of magnetic sensors, which are required in information and communication technology applications; 6) in electrical mobility and energy transformation, where magnetic field measurements are needed for assessing power consumption and the efficiency of components and processes; 7) in space applications, where components and devices need to be free from magnetic fields. Despite the clear needs for low-intensity magnetic field measurements, very few European NMIs and DIs currently have low-intensity magnetic field measurement and calibration capabilities.

Primary standards for magnetic fields are currently based on a nuclear magnetic resonance (NMR) technique, and water samples, with traceability being ensured through links to the standard for frequency. This technique can only be used in DC magnetic field measurements, and in a limited range of magnetic fields, with a lower limit of 10 µT (free precession technique) or 30 mT to 40 mT (forced precession technique). In addition, the NMR method can only be used under strictly specified experimental conditions. Therefore, optimal traceable primary measurement standards, need to be developed for low-strength magnetic fields in the range from 10 µT to 10 mT with target uncertainties of 2 mT/T to 0.2 mT/T.

New and developing calibration laboratories, which have limited infrastructure, require user friendly travelling standards, for use in the measurement of low-strength magnetic fields in the range from 10 µT to 10 mT. Therefore, a robust coil-based secondary standard, and the associated procedures and best practices, need to be developed. In addition, a straightforward traceable method, for the cross-calibration of the secondary standard, needs to be developed with an accuracy of 10^{-4}. This approach will enable the participating NMIs to establish and validate their capabilities related to the measurement of low magnetic fields via an intercomparison and to identify Calibration and Measurement Capabilities for low magnetic fields, based on the validated capabilities, for future submission to the BIPM Key Comparison Database (KCDB).

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The techniques, which are currently used to cancel the effects of the Earth's, and other extraneous environmental, magnetic fields, in a given volume of space, either rely on shielding or magnetic field compensation coils. However, these techniques are becoming less effective due to the effects of urban development and local DC power noise, which hinder the calibration of new low-strength magnetic field measurement systems. Therefore, algorithms and methods, based on closely co-located low-noise sensors and gradient coils, need to be developed for magnetic field compensation during the calibration of low magnetic field systems.

To address these needs, a pan-European metrological infrastructure should be developed and implemented for low magnetic field measurements. A smart specialisation approach is advocated with a range of different routes to traceability: some NMIs need to focus on supporting cutting-edge research on primary standards, with relative uncertainties in the order of 10^{-7}, whilst others need to concentrate on supporting the development of national secondary standards (a travelling coil) for use by the industry, research and calibration laboratories, with relative uncertainties in the order of 10^{-5}. This approach would enable a suitable network of NMIs to be deployed at the European level.

The approaches developed will need to be discussed within the consortium and with other EURAMET NMIs/DIs, e.g. via EURAMET TC-EM (SC Low Frequency subcommittee), IMEKO TC4 and EMNs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the development of metrology capability in low magnetic field metrology.

The specific objectives are

1. To develop optimal primary measurement standards for magnetic fields in the range from 10 µT to 10 mT with an accuracy of 2×10^{-4}.
2. To develop a robust secondary standard, based on a coil, including a traceable method for its calibration, for magnetic fields in the range specified in objective 1 with an accuracy of 2×10^{-4}. In addition, to validate the NMI capabilities related to the measurement of low magnetic fields developed within the project via an intercomparison and to identify Calibration and Measurement Capabilities for low magnetic fields based on the validated capabilities that should be developed for future submission to the BIPM Key Comparison Database (KCDB).
3. To develop algorithms and methods, based on closely co-located low-noise sensors and gradient coils, to compensate for the Earth's, and other environmental (e.g., DC power), magnetic fields, in a given volume of space, which hinder the calibration of low magnetic field systems.
4. To create and implement a pan-European metrological infrastructure for low magnetic field measurements. A smart specialisation approach should be used with a range of coordinated and optimised routes to traceability: some NMIs should focus on supporting cutting-edge research on primary standards, with relative uncertainties in the order of 10^{-7}, whilst others should concentrate on supporting the development of national standards (travelling coils) for use by the industry, research and calibration laboratories, with relative uncertainties in the order of 10^{-5}.
5. To facilitate the take up and long-term operation of the capabilities, technology and measurement infrastructure for low magnetic field measurements developed in the project, by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), and end users (e.g. industry, instrument manufacturers, regulators). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, and EMNs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,

- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 21SCP02 TRaMM and how their proposal will build on this.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.7 M€ and has defined an upper limit of 0.9 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to wide range of sectors (e.g., electric mobility, medical, energy transformation) that need low magnetic field measurements and the metrology community.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.