EURAMET European Association of National Metrology Institutes
EMRP European Metrology Research Programme
Programme of EURAMET

Publishable JRP Summary for Project T4 J07 (JRP EMF and SAR). Traceable measurement of field strength and SAR for the Physical Agents Directive

Project Objectives: The new directive EC 2004/40/EC “Physical Agents Directive” will make the provisions of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) a legal requirement across Europe with respect to the exposure of workers to electromagnetic fields (EMF). The basic restrictions of ICNIRP limit the specific absorption rate (SAR) of radio frequency (RF) power between 100 kHz and 10 GHz, and the incident power flux density (PFD) from 10 GHz to 300 GHz. Existing standards within Europe do not give comprehensive coverage of SAR and PFD over this range. The project, which started on April 1, 2008 aims to provide traceable metrology for SAR and EM field strength measurements at all frequencies that are in widespread public use. It is developing the expertise including contribution to international documentary standards, devices and measurement techniques to make these standards widely accessible for traceable measurements regarding exposure assessment in the environment, product compliance testing, and studies into biological effects of EMF which underpin the international exposure limits.

Planned and ongoing work: Within the project artefact standards for SAR covering the frequency ranges 100 kHz to 380 MHz and 2.6 GHz to 10 GHz, and PFD from 40 GHz to 300 GHz will be developed. To support the new SAR standards and facilitate their accurate and widespread dissemination, liquids will be formulated having similar properties to human tissue for 100 kHz to 300 MHz and 6 GHz to 10 GHz. Improvements will be made to the accuracy and traceability of dielectric measurements of these liquids, including providing better reference data for the liquids used as calibration standards in dielectric measurement systems. New smaller measurement probes will be developed for accurate measurements above 3 GHz and the errors due to isotropy and spatial resolution measured. Techniques will be developed for micro-dosimetry in very small biological samples to facilitate research into biological effects of EMF. Methods for applying low-frequency SAR standards to exposure assessment in industrial and medical environments will be developed, in particular exposure assessment during Magnetic Resonance Imaging (MRI). The effect of signal modulation, multiple frequency sources and broadband signals on the accuracy of field probes will be assessed. A range of commercially available probes and personal RF dosimeters will be tested. Numerical modelling activities are included in all relevant work-packages. They are essential for uncertainty analyses, for optimising measurement techniques and for deciding the best techniques to adopt. Computational simulations also will serve to develop in vivo models for MRI, where SAR metrology is essential for assessing the exposure of patients, in particular of children.

Results and impact: The project has been started with a kick-off meeting on May 21 – 22, 2008 in Braunschweig where all participating partners introduced their laboratories and backgrounds. A board of management for important decisions regarding the progress of the project was established. A detailed planning of the activities within the work-packages has been agreed on and work-package leaders responsible for the organisation of the collaboration within the work-package and reporting have been assigned. Project partners from VSL received extensive training at NPL in dielectric measurement techniques.

First activities have then been started including the design, preparation and characterization of measurement setups for the metrological assessment of communication signals and of reference liquid dielectric material properties. Initial measurements have been obtained on the response of field sensors to pulsed and multi-frequency signals, on the assessment of digital signal properties (error vector magnitude) and on reference liquid and phantom material properties. Optimisation of existing measurement setups have been performed. A thermal sensor concept for ultra-broadband field strength measurements in free-space has been realized and tested as well as planar spiral and bowtie-antennas with a Schottky diode detector. Fundamental development work on the new optic sensor concept has been performed. The work on the power flux density artefacts was started. The investigation of measurement uncertainty of probe calibration was pursued.

Numerical calculations for the SAR distribution in artefact standards, phantoms and biological material monolayers as required for micro-dosimetry have been started. First results include field distributions in field generators, sample containers and SAR distributions in biological layers. Dyes for the measurement of temperature distributions in biological layers have been purchased and the preparation of two confocal microscope measurement setups has been initialized. First measurements for the characterisation of fluorescence dyes were done using a water bath.

The first project results and further procedures have been discussed at the first periodical project meeting which has been performed at UME in Istanbul from October 26 – 28, 2008. In the meantime further progress was achieved in identifying multifrequency environments and in examining the behaviour of many different electric and magnetic field probes while exposed to multifrequency and pulsed signals. In addition to the thermal field sensor which has been improved and characterized further, the fabrication of a planar spiral antenna based diode sensor has been improved. In addition, the concept of a logarithmic-periodic bow-tie toothed antenna with a Schottky diode detector was tested. The source of radiation applied is based on a 4-port vector network analyser with subsequent frequency converters. The frequency range of the wideband radiation source was extended to cover the electromagnetic spectrum up to 325 GHz and then used to characterise and measure the response of the sensors. Using new measurement capabilities, several material parameter measurements have been performed at different institutes for comparison. For low-frequency SAR measurements, MRI scanner measurements on SAR liquids and phantoms have been performed and compared to simulations. Especially the link of external fields at the phantom surface to measurements and numerical results of current densities and SAR inside the MRI phantom was established. Results of several numerical codes were compared and showed good agreement also with results obtained from the Boundary Element Method. For high-frequency SAR measurements, the design of waveguide calibrators has been completed and the assembly of experimental setups has almost been completed. Both numerical calculation and measurements of the input reflection coefficient of the waveguide system based on a TRL-calibration match within the expected uncertainty. First measurements of SAR and calibrations of SAR probes above 6 GHz started using a 3D-high-precision manipulator. For micro-dosimetry on RF exposure, a field generator for a sample container containing the dyes has been designed and further improved. The latest results have been presented and discussed in a Topical Forum during the 20th International Zurich Symposium on Electromagnetic Compatibility (EMC Zurich 2009) on January 14, 2009 and during a project meeting in Helsinki from April 27 – 28, 2009 and in Torino, Italy in October 2009. The overall progress and actual project results have been presented at the International Conference of Metrology in Paris, France in June 2009 and at the AP-EMC Symposium in Beijing, China in April 2010. Besides the research and development activities at the National Metrology Laboratories in order to provide traceability also convenient to use lab equipment such as open-ended coaxial probes and TEM cells to be operated in the industry was tested and verified.

In the future, we expect to generate further competences and capabilities within this project that are necessary for traceable measurements of SAR and EM field strength at all frequencies that are in widespread public use. This will allow to improve the protection of the public in Europe from electromagnetic field exposure as envisioned by the Physical Agents Directive. Furthermore, it will foster research in the field of non-thermal effects of EM waves and in the area of field sensor technology.

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