UNCERTAINTY IN ASSESSMENT OF EMF IN LABORATORY STUDIES AND IN ENVIRONMENTAL EXPOSURE

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Uncertainty plays an important role in the assessment of human exposure since it affects the results of measurements and numerical calculations. This is valid for the evaluation both of radiometric (electric and magnetic field) and dosimetric quantities (induced current J and SAR). Dosimetric evaluation is one of the requirements of a good practice in laboratory studies addressed to investigate the effects of EMF on biological systems. In fact, as required by WHO, biological experiment must be carried out under known and controlled exposure conditions in order to ensure repeatability. Exposure conditions, both for *"in vivo"* and *"in vitro"* studies, must be well characterised (i.e. external electric and magnetic fields) as well as dosimetry. Dosimetric evaluation can be based on analytical (theoretical), experimental and numerical methods. Experimental evaluation of SAR is based on measurement of temperature or of internal electric field "*in vivo"* or inside phantoms, as well as inside cell cultures for "*in vitro"* studies. Dosimetric characterisation in bioelectromagnetics research is also a great concern of the recent EMF-NET publication: "*Recommendations on engineering requirements/aspects for experimental research in Bioelectromagnetics and on quality assurance in Bioelectromagnetics research".* Focusing on RF fields, SAR evaluation is fundamental to correlate biological results to the energy really delivered to the biological target from EMF. Experimental methods are in practice limited to measurements inside phantoms or cell culture in *"in vitro"* studies. Due to their invasive nature, experimental methods in "*in vivo"* studies are affected by several limitations related with the difficulty of realisation of realistic animals models. Even if the accuracy of such methods will be improved in the future, the employ of experimental dosimetry is primarily addressed to the validation of numerical methods, as stated also in the above mentioned EMF-NET publication. As far as concerns numerical calculation, several commercial SW packages implementing numerical methods are available on the market, provided with CAD tools able to realistically represent sources and environment. The reliability of result critically depends on a good representation of the real problem. "*In vitro"* experiments are often carried out under plane wave condition using TEM or GTEM cells as exposure devices, and numerical modelling can be performed by representing a plane wave incident on the sample. The biological material, due to the extremely lower density of cells, is typically represented by means of a thin layer of culture medium, characterized by dielectric properties at the frequency of study. In this case, experimental validation consists of temperature measurements that can be realised by means of thermometric sensors such as fluoroptic thermometers. As far as concerns "*in vivo"* experiments, the matter is more complicated, starting from the representation of the biological target. Several animal models are available, mostly developed by research Institutes, and the accuracy of the results strictly depends on the resolution and good dielectric characterisation of organ and tissues. In the case of TEM exposure systems, experimental validation can be performed by measuring the direct power and the power dissipated by the load. The analysis of uncertainty is an important aspect of dosimetry, but basic knowledge on how to evaluate uncertainty in numerical calculation is still poor. In addition, the methods implemented in commercial software are not standardized yet, especially in the low frequency range, and many gaps still exist in this field, especially in the definition of animal models and knowledge of dielectric properties of tissues.

As far as concerns the treatment of uncertainty (also in environmental measurements), at the moment only standards applicable to emission of specific products give practical

recommendations, that are mostly based on the shared uncertainty budget (or shared risk) approach, but the criteria outlined are not always uniform. Few standards require the uncertainty to be included in the comparison with the limit of exposure. The shared risk approach should be applicable when the end user, or the Authority responsible for control, makes a judgment of compliance and takes some of the risk that the product may not meet the specification. It implies that the actual measured or calculated values must be used for comparison with exposure guidelines, provided that the total assessed uncertainty is less than or equal to permissible or reasonable pre-defined uncertainties, or if the assessment is proven to always overestimate the exposure. Uncertainty values shall be recorded but shall not be included in the comparison. Typical permissible uncertainties defined in relevant standards range from ±2 dB up to ±6 dB for field measurements and are of the order of ±50 % for calculation. From the point of view of practice, the minimum permissible uncertainties for field measurements are of the same order of magnitude of typical performance of instrumentation; on the other side, computational permissible uncertainties seem to be optimistic if compared with realistic evaluations.