Contribution of Statistics to the Numerical Assessment of the Electromagnetic Fields Human Exposure

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Abstract:

1 Exposure Assessment and Deterministic Methods

In spite of the existing international protection limits (e.g. those of the ICNIRP International Commission) and despite the fact that none of the research results have, today, proven any health effects below these limits, the public fears towards electromagnetic fields (EMF) and the radiofrequencies in particular, remains important even if in the same time there is an increasing and intensive use of wireless communication systems. Today billions of people are using wireless systems such as mobile phone, tablet or computer. In such context the EMF exposure, quantified using the Specific Absorption Rate (SAR), must be monitored carefully. The works that have been conducted since twenty years[1, 2], have shown that morphologies, postures, source location and Radio Frequency (RF) bands used are influencing the human exposure. In the 90's the first objective was to define methodologies able to check the compliance (to the recommended limits) of the EMF emitted by wireless communication equipment (e.g. mobile or base station). To achieve this objective and overcome the possible large variability of the exposure, "worst-case" scenarios (e.g. phantom head) have been designed by international bodies such as CENELEC, IEC or IEEE. These protocols and methods have been successfully used to define such compliance tests. Unfortunately such approach, if useful for compliance checking, is not suitable to assess the real personal exposure [3]. Such "worst case" approach has been first challenged with the epidemiological studies (e.g. the international INTERPHONE study) that request the real exposure and not a maximum. The need of a comprehensive exposure assessment has been reinforced with the increasing and versatile use of the wireless communication systems. Today these systems can emit in different RF band and in different ways depending on the application, they can be used in versatile use (listening, watching, ...).

2 Contribution of Statistics to Human Exposure Assessment

In the 2000s new approaches, involving statistics, have been investigated to respond to these questions and be able to handle new usages such as those of children who, at earlier and earlier ages, use tremendously wireless communication systems. The numerical method, mainly used in bio-electromagnetism, to estimate the human exposure induced by EMF, is the finite difference in time domain (FDTD). This method is based on an explicit iterative calculation of the electric and magnetic field (linked by the well known Maxwell equations) over an orthogonal grid. The main advantage of the FDTD is to proceed without any matrix inversion that can be cumbersome. The main problem of the FDTD is the time computation that can be very large (i.e. few hours if calculation involved the whole body). Large efforts have been achieved toward high performance calculation using parallel computation and recently graphic processors unit. But even with these efforts, the time computation is still important and is not compatible with Monte Carlo Method. To overcome this issue, efforts have been dedicated to built simplified surrogate models. Works have be done to use the polynomial expansion with the coefficient of the polynomials estimated using projection methods and smart grids[4]. The results of these studies showed that this approach is still not compatible with the FDTD even if reducing the number of computation. For instance a quite simple problem such as a phone close to the head, involving 4 input parameters, governing angles and location, can request few hundred of simulation. To reduce the number of simulations and taking into account previous work carried out in mechanical domain, a sparse polynomial chaos (PC) expansion (using a least angle regression method) combine with a regression and an iterative planning experiment has been used to built a surrogate model with a minimum calculation [5]. This approach has been able to reduce significantly the number of simulations but has limited abality to manage the accuracy of quantile estimation. Due to the influence of the morphology [2] this quantile estimation is a key question to determine the threshold of the Whole Body SAR (WBSAR) at 95 % for a given population[6]. A similar problem is the fetus exposure induced by plane wave having arbitrary incidence[7]. In these case the challenge is to built a parsimonious iterative planning experiment able to select additional calculations increasing the accuracy of the quantile estimation. To achieve this objective, Gaussian Process and sequential planning numerical experiments method [6, 7] have been studied. Gaussian Process Shrunk and existing Stepwise Uncertainty Reduction have been studied to select iteratively new calculation with a strong constraint on the minimum of calculation to performed. The uncertainty estimation obtained with PC is often a global one (using bootstrap or leave one out methods) and since method such as Kriging has shown a good ability to address this problem, on going work are performed to combine Kriging and PC to build an efficient and parsimonious iterative planning able to assess quantiles and the associated uncertainties.

3 Conclusions

With the versatile use of wireless, the exposure assessment have to handle complex and variable configurations. The usual deterministic approaches are not able to handle such variability and dosimetric calculations can be cumbersome. As described in previous sections, statistical methods allow to handle complex and variable configurations that cannot be managed using the regular deterministic approaches, These methods have shown a good capability, in bio-electromagnetism where the number of input can be important. During the presentation, examples will be given to illustrate the challenges and methods used to characterise statistical distribution of the local and whole body human exposure.

References

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