Variability and Sensitivity Analysis of Global Population Exposure to 3G-induced EMF

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Ph.D. expected duration: 2014-2017

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Abstract:

To respond to public risk perception about exposure to Radio Frequency (RF) Electromagnetic fields (EMFs), it has become necessary to characterize the real RF human exposure to such fields. In most studies dedicated to the risk assessment of EMF exposure, a worst-case approach is often adopted. Furthermore, EMF exposure levels are quantified in terms of Specific Absorption Rate (SAR) expressed in W/kg and of incident field (e.g., electric field expressed in V/m), respectively, induced by maximum EMF radiations originating from personal wireless devices and from BTS (downlink). However none of these approaches alone allows assessing the real global population exposure to RF EMFs (e.g., combining the uplink and downlink exposure).

The aim of this study was to develop a simplified exposure index that would characterize the average exposure of a population taking into account both the exposure induced by EM radiation emitted by wireless devices and received from base stations (BTS) or access points. This simplified exposure index was developed based on the new exposure metric named Exposure Index (EI) implemented in the Low EMF Exposure Future Network (LEXNET) project [4]. In its raw definition, EI is a complex index to evaluate and calculate. Many parameters influencing the exposure should be taken into account, e.g., life segmentation data (how people segment a typical day for example), reference SAR data (a set of EMF exposure values for typical postures and usages of mobile devices), Information Communication Technology (ICT) usage data (average communication duration, average volume of data traffic, etc.) and network data (throughput, received and emitted powers, respectively from BTS and by wireless devices). In fact, studies analyzing the day-to-day exposure to EMF are facing the characterization and quantification of ICT usage data. Such information is fundamental to analyze the differences among mobile device usages. In addition, traffic load has a strong influence on emitted and received powers and network performances (e.g., mobile throughput), all of them directly impacting the EI. Making things more complicated these influencing parameters (ICT usage data, emitted and received powers, mobile throughput) should not be regarded as constant values but highly variable. As a consequence, how to manage uncertainties linked to these influencing parameters and how the EI varies due to these random parameters are the main issues.

The current contribution is the evaluation of EI in order to characterize the day-to-day EMF population exposure taking into account the influence of variability and uncertainties linked to ICT usage and network data (EMF radiations originating from BTS and wireless devices and uplink throughputs). Thereby, a sensitivity analysis can be carried out in order to assess the influence of these parameters on EI for the purpose of simplification. To achieve this goal, an EI evaluated over 24 h for 3G macro network in a dense urban area was considered. The formalization of EI metric passes through the characterization of variability and uncertainties linked to the input random variables:

ICT usage data were obtained through measurement probes installed at the Radio Network Controller level of 3G Orange network. Hourly usage (e.g., voice call duration, uplink and downlink traffic volumes) were recorded from a monitored urban area in the district of Paris during one week. Based on collected data, differences of 3G ICT usage among users were analyzed statistically. It was observed that usage is completely unbalanced among all users. As a result, users were classified into three different ICT user profiles: heavy, moderate, and light. In-depth statistical analysis (SQL, AIC, R^2, KS test) enabled to identify the characteristics for different profile usages.

Network data were simulated through a 3G radio network planning tool [2]. This tool is based on a vast amount of data extracted from geographical area, building locations, network deployments, etc. It offers an accurate estimation of the network quality, the throughput, etc., while at the same time it requires a large amount of preparing and computing time. Hence, an advanced statistical method of Polynomial Chaos expansion based on Least Angle Regression [1] was used to predict the random system response Y according to the random input variables X. Finally, 50 simulations were performed to build the meta-models for network data (the determination indicator Q^2 was estimated around 90%). In addition, a statistical model was selected for each variable based on the 10^4 executions and further used as inputs to evaluate the EI.

To the end of assessing the variability of EI with respect to ICT usage data and network data, the Monte Carlo method was adopted. It is important to note that the dependence exists between some network data. Therefore, the dependence among these variables was modeled using Normal copulas. 10^6 sample sets were taken into account to guaranty the large amount of simulations required by Monte Carlo method. By aggregating all executions of input variables using the EI equation, the global exposure of a population in an urban area considering a macro 3G network was assessed. Finally, a sensitivity analysis was carried out to assess the influence of input parameters on EI. Variance based sensitivity indices, introduced by Kucherenko and colleagues in [3], were adopted in the presented study since it is particularly appropriate in cases where input parameters are not independent. Indices of Kucherenko are evaluated based on Monte Carlo simulations and dedicated to describe the influence of each input parameter on the variance of the output, which represents the EI in our study. Both the first order and total sensitivity indices were derived as generalizations of Sobol sensitivity indices.

References

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Short biography – Master of Telecom Bretagne (2013), is currentl involved in a PhD thesis in IMT Atlantique, Orange Labs and Telecom ParisTech. Her research focuses on evaluating via dosimetric tools and statistical methods the global exposure of a population to RF-EMF.