Measurement-Based Assessment of Uplink, Downlink, and Global RF-EMF Exposure Using the Exposure Index

Meryem Bekkouch[1,2], Shanshan Wang[2], Jiang Liu[2], Theodoros Samaras[3], Lamine Ourak[4], Yarui Zhang[5], Serge Bories[6], Emmanuelle Conil[7], Zain Haider[8], Mohammed Anisse Moutaouekkil[1], Chakib Taybi[1], Joe Wiart[2]

[1]Mohammed First University, ENSA Oujda, Laboratory of Electronics and Systems, Morocco; [2]Télécom Paris, LTCI Chaire C2M, Institut Polytechnique de Paris, France; [3]Aristotle University of Thessaloniki (AUTH), Greece; [4]EXEM, Toulouse, France; [5]ENS Paris-Saclay, Laboratoire SATIE, France; [6]CEA LETI, Grenoble, France; [7]ANFR, Maison Alfort, France; [8]MVG, Villejust, France

meryem.bekkouch@ump.ac.ma

1. Objectives

This study was conducted within the framework of the European project **SEAWAVE** and the French ANSES project **EXPLORA**. Its main objective is to characterize radio-frequency electromagnetic field (RF-EMF) exposure induced by wireless communication networks. This is carried out by jointly analyzing uplink (UL) and downlink (DL) contributions and combining different methods such as measurement and simulations. A global assessment of exposure is performed using the **Exposure Index (EI)** under realistic mobile phone usage conditions.

2. Uplink and Downlink Measurements

Within the SEAWAVE and EXPLORA projects, uplink (a.k.a UL) exposure measurements were carried out under realistic mobile phone usage scenarios. These measurements focus on user-related emissions generated by mobile devices during typical use and have been previously reported in [1,2]. In this studies UL power has been used to assess the power absorbed in human tissues using numerical methods. Not only UL has been studied but also the Downlink RF-EMF. On the one hand ANFR carry out downlink RF-EMF (a.k.a DL) measurement [3] for long time. On the other hand EMF linked to DL were conducted in urban environments as part of the SEAWAVE project. As for the UL simulations have been carried out to assess the RF power absorbed in human tissues (ie the exposure) [2]. A measurement-based assessment relying on several complementary methods was implemented, allowing for a robust characterization of environmental downlink exposure [4].

3. Global Exposure Assessment using Exposure Index

The Exposure Index (EI) was originally introduced within the European LEXNET project [5] as a global metric designed to quantify and compare RF-EMF exposure in wireless communication networks by jointly accounting for uplink and downlink components. We used EI to carried out a statistical analysis of the global RF-EMF exposure. Exposure scenarios were defined by combining usage duration, application type, and user posture. Uplink exposure was evaluated for four representative mobile applications (VoLTE, VoIP, video streaming, and data usage) and five realistic user positions, considering both 4G and 5G technologies. For each application, exposure levels were modeled as a function of user position for the considered scenarios. The uplink Exposure Index (EI_UL) was obtained by aggregating the contributions of all applications and positions. The global Exposure Index (EI_global) was then derived by combining EI_UL with the downlink Exposure Index (EI_DL), providing a statistical distribution of RF-EMF exposure in current mobile network deployments. The resulting exposure distribution was characterized using its four statistical moments: mean, variance, skewness, and kurtosis. By jointly considering uplink and downlink contributions, RF-EMF exposure can be statistically characterized at the organ level.

4. Conclusions

The proposed approach enables a comprehensive assessment of global RF-EMF exposure by integrating measurement-based uplink and downlink data within the Exposure Index framework. It offers a robust and consistent methodology that combines simulation-based and measurement-based techniques to evaluate population exposure. This approach characterizes exposure through the moments of its distribution and allows for meaningful comparisons of exposure levels across contemporary mobile communication networks.

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