Polynomial Chaos applied to the exposure assessment of child to Radio-Frequency field emitted by tablet devices

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The public concern toward the exposure to Radio-Frequency Electromagnetic Fields (RF-EMF) is continuously growing, due also to the increasing use of wireless communication system. The assessment of real exposure scenarios is still an open issue, due to the variability of the input parameters that influence the exposure itself (e.g., the source design, the frequency band used, the morphology of the subject exposed). Classical electromagnetic computational techniques are typically leading to highly time consuming simulations, if the variation of the, before mentioned, parameters is taken into account. A promising alternative to this issue is given by Polynomial Chaos (PC) theory, which is an efficient method to assess the variability of exposure at a lower computational cost. In this study (*ANSES project Acte http://whist.mines-telecom.fr*), PC theory has been applied to study the exposure of a 1-year-old child to a 3G tablet emitting at the frequency of 1940 MHz with 1 W input power. The exposure has been characterized in terms of Specific Absorption Rate (SAR). A PC expansion has been built to estimate the whole-body SAR and the SAR in the brain, separately, to assess the variability of the child exposure with the change in the tablet position.

The Polynomial Chaos is a spectral method and consists in the approximation of the system output Y in a suitable finite - dimensional basis $(\psi_j(\mathbf{X}))_{0\le j\le P-1}$,made of orthogonal polynomials. A truncation of this polynomial expansion can be performed:

$$Y = M(\boldsymbol{X}) = \sum_0^{P-1} a_j\, \psi_j(\boldsymbol{X}) \qquad (1)$$

In this case Y is the whole-body SAR and the SAR in the brain, **X** is the random input vector, made of 4 independent parameters, supposed to be uniformly distributed and representing the translation of the tablet along the axis x,y, z and the rotation of the tablet in the xz-plane, and a_j are the coefficients to be estimated. The polynomial basis has been built using Legendre polynomials (Xiu et al., *SIAM Journal on Scientific Computing*, vol. 24(2), 2002) and the coefficients a_j have been estimated by regression and Least Angle Regression (LAR) algorithm (Efron et al., *The Annals of Statistics*, vol. 32(2), 2004). The best solution among the models generated by LAR has been chosen through a leave-one-out (LOO) cross-validation. The observations $\mathbf{Y_0}$, used in the LAR algorithm, have been estimated through computational dosimetry by means of a numerical model of the child (Li et al., *Bioelectromagnetics*, 36, 2015). The PC expansions, achieved by this procedure, have been validated by calculating the percentage mean square error (pMSE) on a validation set $\mathbf{Y_{val}}$ different from $\mathbf{Y_0}$. The PC expansions of the whole-body SAR and the SAR in the brain of the baby were built by means of 60 observations with a pMSE equal to 0.02% and 0.28%, respectively, calculated on a set $\mathbf{Y_{val}}$ of 30 observations. The mean and standard deviation of the SAR were analytically derived from the PC coefficients, and the coefficient of variation CV, defined as the ratio of the standard deviation to the mean value, was used to estimate the variability of the exposure. Finally, a global sensitivity analysis, expressed as Sobol indices, has been carried out to evaluate which input parameters influence more the exposure. The CV was found up to 5.3% and 18% for the whole-body SAR and the SAR in the brain, respectively. The global sensitivity analysis shows that these observed CV are mostly due to the translation along x- and y-axis for the whole-body SAR (Sobol indices of 49% and 34%, respectively), and to the rotation of the tablet in the xz-plane for the SAR in the brain (Sobol index up to 66%).

In this work Polynomial Chaos (PC) has been used to assess the variability of exposure of a baby to a 3G tablet at RF. PC resulted an efficient method to build accurate approximations of the SAR in the whole-body and in the brain of the baby with only 60 observations, and with an error lower than 0.3%. The analysis of the RF exposure showed that the variations due to the change in the tablet position are up to 18% in the brain and that this variation is mostly due to the rotation of the tablet in the xz-plane.