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A Framework for the Statistical Analysis of a Vircator Surrogate Model

Mae AlMansoori*(1)(2), Ernesto Neira(1), Sebastien Lallechere(3),Felix Vega(1)(4), Lars Ole Fichte(2), Zouhair Nezhi(2), Chaouki Kasmi(1)(2), and Marcus Stiemer(2)

(1) Directed Energy Research Centre, Technology Innovation Institute, Abu Dhabi, United Arab Emirates.

(2) Faculty of Electrical Engineering, Helmut Schmidt University, Hamburg, Germany.

(3) Université Clermont Auvergne, Institut Pascal, Sigma Clermont, Clermont-Ferrand, France.

(4) Universidad Nacional de Colombia, Sede Bogotá, Colombia.

Recently, a significant number of statistical methods have been proposed to assess the influence of uncertain parameters in different fields including Electromagnetics [1]. The efficiency of High Power Microwave (HPM) radiators was further investigated by quantifying the uncertainties as reported, e.g., for the Vircator in [2]. The Vircator is known to be a low efficiency high power microwave source depending on complex phenomena like plasma expansion and subject to high shot-to-shot variability. A surrogate model allowing for the estimation of the peak power output and the radiation frequency of an axially symmetric Vircator has been proposed in [3] that depends on the following inputs (in the current work considered as Random Variables (RVs)): the transparency of the anode, the radius of the drift tube, the radius of the cathode, the anode-cathode gap, and a source model with a voltage, an inductance, a capacitance, and an internal resistance. A generalised Design of Experiments (DoE) technique [1] was applied to identify and quantify the variation resulting from the RVs and their interactions (256 combinations were studied covering all possible combinations of the latter eight inputs considered either as RVs or fixed at their mean value and considered deterministic). Focusing on the central tendencies, Sobol' indices and ANOVA combined with Stochastic Collocation [1] have been applied to study the peak power sensitivity with respect to the variability of the input parameters. With regard to outliers, the Peaks Over Threshold (POT) method was implemented using the Generalised Pareto Distribution (GPD) to analyse the extreme values higher than 95 % quantile-threshold deduced from a quantile-to-quantile screening. The influence of the RVs on the GPD parameters (scale and shape) [4] has been studied considering all possible combinations of RVs.

During the presentation, a computationally low cost framework for statistical analysis applied to a Vircator surrogate model will be presented demonstrating the possibility of maximizing peak power output with a limited deviation of the radiation frequency from the point of design. Comparing the influence of the RVs on both central tendencies and extreme values, it has been observed that the peak output power can be increased statistically in the sense of obtaining a heavier distribution tail on the right hand side while reducing the left one (30 % increase compared with the point of design). The proposed framework has been compared with reported experimental results such as the perveance variability [5] that can be captured from the surrogate model by identification of an appropriate statistical process.

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