Statistical Approaches for Surrounded Antennas

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Context

The recent growth of Internet of Things (IoT) has brought a variety of services and applications in our everyday life. The advent of 5G communications cellular systems and beyond with an increased data rate, a reduced end-to-end latency and an improved coverage is considered to be a major driver for the development of a truly global IoT. The various nature of the connected objects can be highlighted through different new areas of application. For example, IoT offers a wireless low-cost high-density distributed sensor-based tool for Structural Health Monitoring (SHM) which can replace a regular maintenance into a more cost-effective condition-based one. In a completely different context, Wearable Health Monitoring Systems (WHMS) deploy various types of miniature wearable or implantable sensors to improve the supervision of patients. Besides these specific applications, IoT can bring solutions to the recent public health problems by providing individuals with reliable information. For example, nowadays a public issue concerns the food quality and traceability. Another example is the integration of sensors (or small cells base stations) in the urban infrastructure.

Despite the diversity of the cited applications, some common aspects can be recognised regarding the conditions under which the communicating sensors or terminals operate:

- A partial or uncertain knowledge of the close environment
- Intrinsic variability of the sensor or terminal support

Given the complexity and variability of the environment or of the device itself, a purely deterministic approach to model antennas and their interactions with their immediate environment would not be realistic. In this context, the assessment of antennas performance must be revisited through a statistical and parsimonious modelling approach using efficient surrogate models (substitution or metamodels).

This PhD proposal aims to develop and establish on a solid basis a statistical methodology to address the issues of surrounded antennas. The ambition is to pave the way to handle such issues in an applicative context, with a potential industrial impacts. Different domains such as textile antennas, wearables, "soft electronics", IoT, RFIDs, etc. are of concern.

PhD proposal

The use of Uncertainty Quantification (UQ) techniques for the robust design of engineering systems has gained tremendous interest over the last decade. Based on a computational model of a system, UQ first consists in representing the variability of the input parameters by an appropriate probabilistic model. The sensitivity analysis aims at determining which input parameters play the most significant role in terms of output uncertainty. All uncertainty quantification techniques rely upon repeated runs of the simulator based on different values of the input parameters.

The well-known Monte Carlo simulation technique, which uses a large number of random samples of input parameters is not affordable in practice when complex simulators (such as EM softwares) are used. Surrogate modelling techniques such as polynomial chaos expansions (PCE) [1], Kriging [2], low-rank tensor representation [3] and neural networks [4] have been developed to bypass this computational issue.

In the domain of antenna design and optimisation, advanced statistical techniques and surrogate modelling have proved to be useful by taking into account important degrees of freedom and numerous fabrication constraints. The examples go from the design of UWB patch antennas [5] or deformable textile antennas [6] to the design of antenna arrays [7].

In this proposal, "surrounded antennas" refer to configurations in which antennas with given intrinsic parameters are perturbed by their close environment (other radiating elements, nearby scatterers, support objects, human body, etc.) The characterisation of surrounded antennas (body centric wireless network, antennas on complex platforms, RFID tags, etc.) is still a real challenge. The literature based on statistical approaches for this category of antennas remains still limited and relies mainly on conventional techniques, such as the Monte Carlo method [8], [9]. Moreover, to our knowledge these statistical techniques have not been used to analyse the performances of global system observables (key performance indicators) at the system level.

With respect to the state of the art, the objectives of this PhD thesis are:

- To develop an appropriate and robust surrogate model for surrounded antennas in an uncertain or partially known environment;
- To assess the antenna and the whole system performances statically using the obtained antenna metamodel.

Work plan

Build "antennas" metamodel: A number of pertinent input parameters are identified and their variations are modelled using appropriate probability density functions depending either on the design, usage, close environment, application and fabrication of the antenna. Using the appropriate statistical techniques, an accurate surrogate model for the "variable" antenna is introduced.

Statistically assess "antennas" performance: The substitution model of the variable antenna is used to quantify the impact of the variability of the input parameters over the outputs of the antenna. The quantities of interest for the antenna (such as return loss, gain, etc.) calculated from the outputs of the substitution model are called antenna's output indicators.

Statistically assess "system" performances: The substitution model of the variable antenna is integrated in a higher level system simulator. The impact of the variability of the global system parameters, along with the local variability of the antenna itself, over the system outputs is quantified. The quantities of interest for the system output (such as read-range in an RFID system, BER for a data communication system, etc.) are called Key Performance Indicators (KPIs).

Applicant profile

This PhD offer is intended for the candidates having a Master's degree in « 3EA » or an equivalent degree in « Electrical engineering ». The following conditions are required:

- Solid knowledge in electromagnetics and applied mathematics
- Interest for experimentation
- Autonomy in computer programming

Contact

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The application file should include CV, statement of purpose, recommendation letters and all academic transcripts and may be addressed by email to Shermila Mostarshedi (Shermila.Mostarshedi@univ-eiffel.fr).

ESYCOM laboratory

The ESYCOM laboratory is within the field of communication systems, sensors and microsystems for the city, the environment and the person.
The topics of interest are more specifically:

- antennas and propagation in complex media, photonic-microwaves components;
- microsystems for environmental analysis and pollution control, for health and the interface with living organisms;
- micro-devices for ambient mechanical, thermal or electromagnetic energy harvesting.

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