Project in the frame of Graduate Program CODS
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Statistical approaches for antennas in uncertain conditions
Application to IoT

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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 applications. 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.

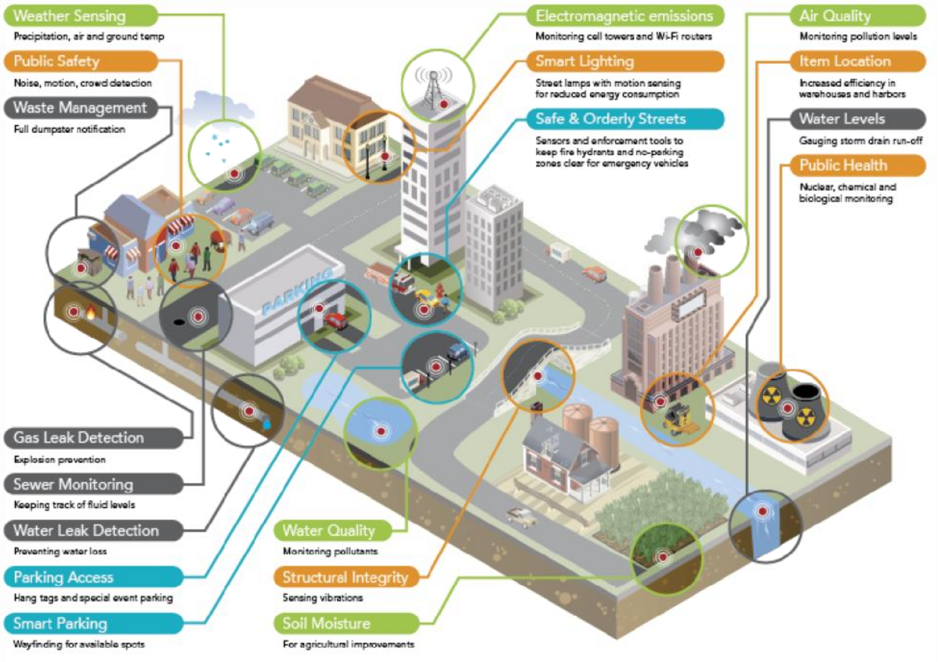

Figure 1. Ubiquitous sensor network in smart cities (https://fybr.com/)

Despite the diversity of the cited applications (Fig. 1), 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 deformable antennas and/or 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) modeling approach using efficient surrogate models.

Configurations in which antennas with fixed intrinsic parameters are perturbed by their close environment (nearby scatterers, support objects, human body, etc.) is generically called **“Surrounded antennas”**. 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 is growing [1], [2] but remains limited and relies mainly on conventional techniques, such as the brute-force Monte Carlo method [3], [4]. The well-known Monte Carlo simulation technique, which uses a large number of random samples of input parameters is not suitable when complex simulators (such as EM softwares) are used. Surrogate modelling techniques such as polynomial chaos expansions (PCE) [5] and Kriging (as known as Gaussian process modelling) [6] have been developed to bypass this computational issue. According to a few studies, advanced statistical techniques and surrogate modelling have proved to be useful in antenna design and optimisation, however these techniques have not been used to analyze the performances of global system observables (key performance indicators) at the system level [1], [7].

This project prepares the preliminary steps for a new approach to statistically quantify the performance of antennas operating in uncertain conditions. The main objectives of the project are divided into short and long terms categories as follows:

Short term objectives:

Surrogate (substitution) model: At least one advanced statistical technique is identified to be appropriate for the antenna modelling. To implement the model, the UQ LAB tool (Fig. 2) which is developed at ETH Zurich by a team of statisticians is essentially used.

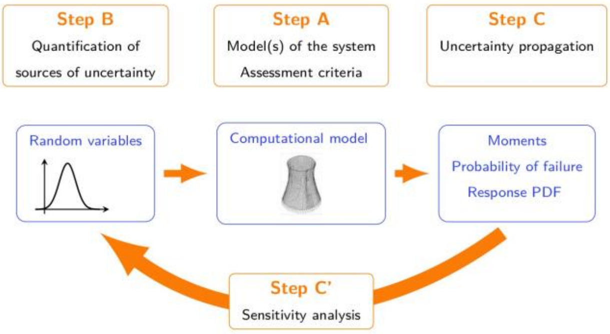

Figure 2 . General framework for uncertainty quantification (www.uqlab.com)

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 technique, an accurate substitution model (metamodel) for the “variable” antenna is introduced (Fig. 3).

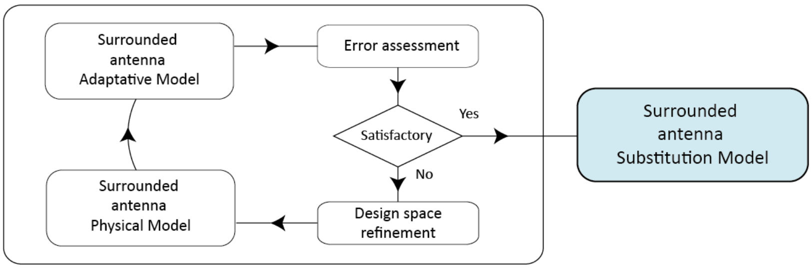

Figure 3 . Substitution model optimisation process

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. In this proposal, 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 (Fig. 4).

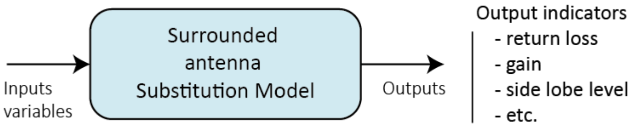

Figure 4 . Substitution model exploitation at the antenna level

Long term objective: (*Out of the scope of the project*)

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. In this proposal, 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).

References:

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