Statistical Investigation of a Dual-Band Wearable Patch Antenna

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***Abstract*—We present a stochastic modeling strategy for studying a wearable textile antenna under different manufacturing conditions. The studied device is a patch antenna designed for energy harvesting, which operates at the GSM and DCS bands, 900MHz and 1800MHz, respectively. The performance of the conductive patch printed on a textile substrate backed by a ground plane is investigated. A stochastic approach is employed to assess the variability of the observable because of the uncertainties introduced in the manufacturing process, such as laminating and embroidering.**

Keywords—Wearable Textile Antennas, Stochastic Analysis;

I. INTRODUCTION

Recently, there has been an increasing interest in the development of wireless communications networks (WCN). More specifically, WCN based on wearable antennas have become attractive, owing to their flexibility and ease of integration into the clothing. Applications of smart antennas integrated in clothes are expected to emerge in various areas such as military, medical and space.

Not unexpectedly, performance of these flexible and wearable antennas are likely to deteriorate depending upon the fabrication process, as well as surrounding factors. In fact, the antenna may be fabricated and integrated into the clothing in two different ways, namely laminating and embroidering. The geometrical dimensions of the patch as well as the physical parameters such as the conductivity of the metallic parts and the permittivity of the substrate are susceptible to variations. The laminating process is a technique where conductive and dielectric sheets are glued together with a thermal adhesive, using ironing. The thickness and physical properties of the conductive fabric are affected by the presence of the adhesive sheet and the ironing process. As for embroidering, the density of the stitches is the main cause of the variability of the conductivity of the patch antenna. Moreover, once the antenna is integrated into the clothing, the surrounding materials such as the human body, and the flexibility of the textile antenna may compromise its effectiveness. Consequently, it becomes necessary to investigate the effects of these variations on the performance of the textile antenna. In this work, we present a stochastic analysis based on the use of the polynomial chaos expansion (PCE) technique. The following section presents only a very brief summary of this method; interested reader is referred to article in [1] for a detailed description of the PCE method.

2. STOCHASTIC ANALYSIS

The Polynomial Chaos Expansion (PCE) technique is used to construct a surrogate model, which is intended to replace the forward computational model. It has been shown that the PCE is more efficient in terms of the computation time when compared to the well-known Monte Carlo method. The PCE is based on a statistical approach where the model parameters are considered to be randomly distributed variables. Assuming that the Probability Density Function (PDF) of the input variables **X** is known, the corresponding statistical output (Y) of the system can be expressed as:

$$Y = \sum_{\alpha \in \mathbb{N}^m} a_\alpha \psi_\alpha(X) \qquad (1)$$

where a_α are the unknown coefficients to be determined, $\psi_\alpha(X)$ are the basis function and α is the multi-index that identifies the components of $\psi_\alpha(X)$. The unknown coefficients a_α are usually determined by truncating the polynomial expansion, and retaining only a subset of the polynomials. The Least Angle Regression selection (LARS) is usually preferred for the truncation. The relative influence of each input parameters onto the output of the model is assessed by using the Sobol indices [1].

II. RESULTS

A dual band antenna operating at 900MHz and 1800MHz is considered in this work and is shown in Fig. 1. This antenna has been previously investigated both numerically and experimentally in [2]. The materials used for manufacturing the antenna using the laminating process are presented in Table 1. The geometrical dimensions of the antenna are the same as given in [2]. In order to keep the analysis simple and to avoid overloading it, only a limited number of parameters are retained for consideration. Beside the ones given in Fig. 1, the studied parameters are the height (*hsub)* of the substrate, its permittivity (*epsC), a*nd the conductivity (*condZ)* of the patch as well as of the ground plane.

Table 1: Materials used for manufacturing the antenna

	Fabric	Thickness (mm)	Dielectric constant	Tangent Loss
Substrate	Cordura®	0.5	1.9	0.0098
Conductive materials	Zelt	0.06	Conductivity (S/m)	
			1.75105×10^{6}	

The variability of the geometrical dimensions can be attributed to the imprecise nature of the fabrication process. Our motivation for including the height of the substrate, as well as the physical parameters such as the conductivity and the dielectric constant, is based on the analysis reported in [2]. For instance, the height of the substrate is likely to change due to compaction during the lamination process by ironing. Also, the adhesive sheet used to glue the conductive parts to the substrate is likely to change the permittivity and decrease the conductivity of the conductive fabric.

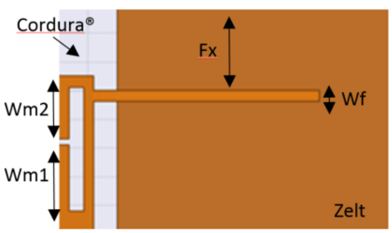
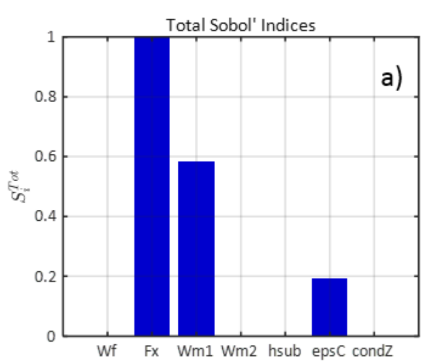


Fig.2. Sketch of the dual band antenna

In this presentation, the output parameter examined is the resonance frequency, and we would like to determine how much the resonance frequency is shifted as the input parameters are varied randomly. Figs. 3 and 4 present our preliminary results on the PDF of the output and the Sobol indices that display which input parameter has the most influence on the resonance frequency. In this work, we have assumed that the input parameters have a 5% variation. The corresponding standard deviations σ for both resonance frequencies are presented in the figures which also show the mean value μ is the coefficient of variation Δ.



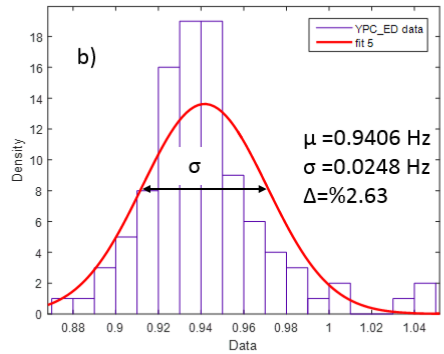


Fig.3. Sobol indices: (a) and the PDF of the resonance frequency; (b) around 900MHz

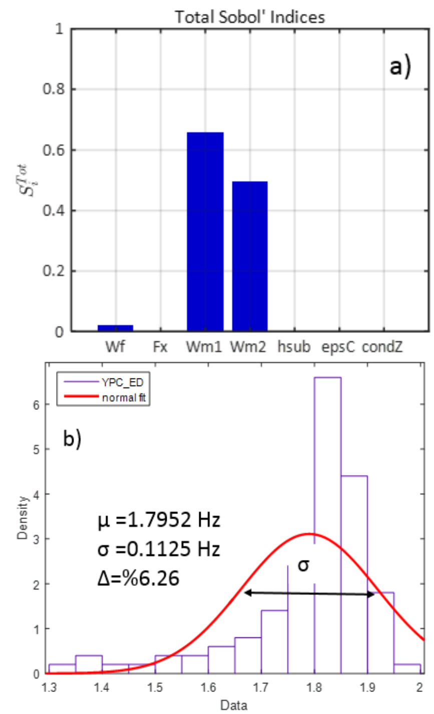


Fig.4. Sobol indices: (a) and the PDF of the resonance frequency; (b) around 1800MHz

III. Conclusion

In this work, we have investigatedd the performance of a dual-band textile antenna, which is shown to be dependent on the uncertainty of the design parameters, presumably introduced by the manufacturing process. The PCE technique is employed for this purpose.

References

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