SENSITIVITY ANALYSIS AND PARAMETRIC OPTIMIZATION AS POWERFUL TOOLS FOR INDUSTRIAL PRODUCT DEVELOPMENT

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SUMMARY

Numerical simulation has become an important tool for industrial product development. Due to this virtual development, many tests can be performed within a virtual environment instead of real laboratory tests. This will decrease the development cycle time for the development of new products or new product series. By using analytical and numerical methods for this virtual testing, new possibilities have arisen in order to automatize steps in this manually driven process. One possibility is the parametric optimization framework, where specific properties of the virtual product are represented by adjustable parameters.

By means of the virtual design of a dual band antenna the framework for sensitivity analysis and efficient optimization is demonstrated. The design of multiple band antennas is not straight forward: A structure has to be found that has several resonances, one at each of the desired transmission frequencies. Furthermore, those resonances have to be of the right width and the radiation pattern has to be of the desired shape. In order to meet the various design goals of having the right transmission frequencies, the antenna geometry needs to have enough free parameters that can be adjusted. With help of ANSYS HFSS a fully parametric simulation model has been generated, which is ready for parametric sensitivity study and optimization. By using advanced surrogate models the influence of the geometry parameters to the response spectrum could by analysed and suitable formulations for reaching the optimization goals could be achieved.

In this paper a dual band slot antenna is investigated according to [1] and [2], the desired transmission frequencies are given at 2.4GHz and at 5.8GHz where the return loss should be at least -18dB. The analysis in this paper has been done by using specific scalar outputs of the return loss spectrum within a parametric approach. A parametric free analysis by using field meta-models has been presented earlier in [2]. Further details w.r.t. the second approach will be given in the conference presentation.

1: The dual-band antenna optimization task

In Fig. 1 the geometry of a dual-band antenna for WLAN applications is shown. Based on a parametric description of the geometry, the return loss in the frequency spectrum has been analysed with ANSYS HFSS. The initial return loss spectrum is shown in Fig. 1. As optimization task, the return loss at two desired transmission frequencies, 2.4 and 5.8 kHz, should be minimised. The parametric geometry model consists of nine modifiable parameters as the width and length of the slot (ws, ls), the distances of the U-shaped conductors in the ground plane to the boundary of the slot on x- and y-direction (gap1, gap2), the distance of the two conductors in the ground plane to each other (dd), the width of the conductors in the ground plane in x- and y-direction (w1, w2), and length and width of the micro strip feed line on the bottom (lf, wf).

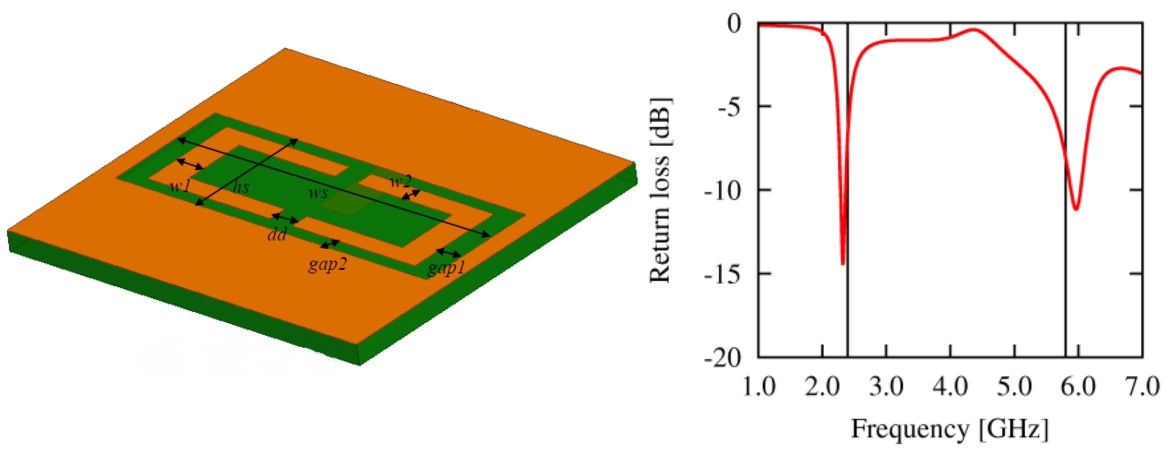

Figure 1: Parametric geometry description of the investigated dual band antenna (left) with initial return loss spectrum (right) and desired sending frequencies

2: Sensitivity analysis and optimization

In order to formulate the optimization task most suitable, first a sensitivity analysis is performed. For this purpose an optimized Latin hypercube sampling [3] is generated as Design of Experiments scheme within the given parameter bounds. For each sample the full return loss spectrum is evaluated by the HFSS solver. From the spectrum the amplitude values at 2.4 and 5.8 kHz on the one hand side and the minimum amplitude values as well as their positions on the other side are extracted from the spectrum. With help of the Metamodel of Optimal Prognosis (MOP) approach [4] an optimal mathematical surrogate model was generated for each scalar response value. As a result of this investigation, it was observed that the positions of the minima are almost linear functions with respect to the geometry input parameters. In contrast to this the amplitude values at 2.4 and 5.8 kHz as well as the amplitude values of both minima show a much more nonlinear behaviour as shown in Fig. 2. The variable sensitivities are estimated with help of the MOP and are shown in Fig. 2. They quantify the variance contribution of each input parameter with respect to the response. The last column indicates the prediction quality of the individual optimal surrogate models quantified by the explained variation.

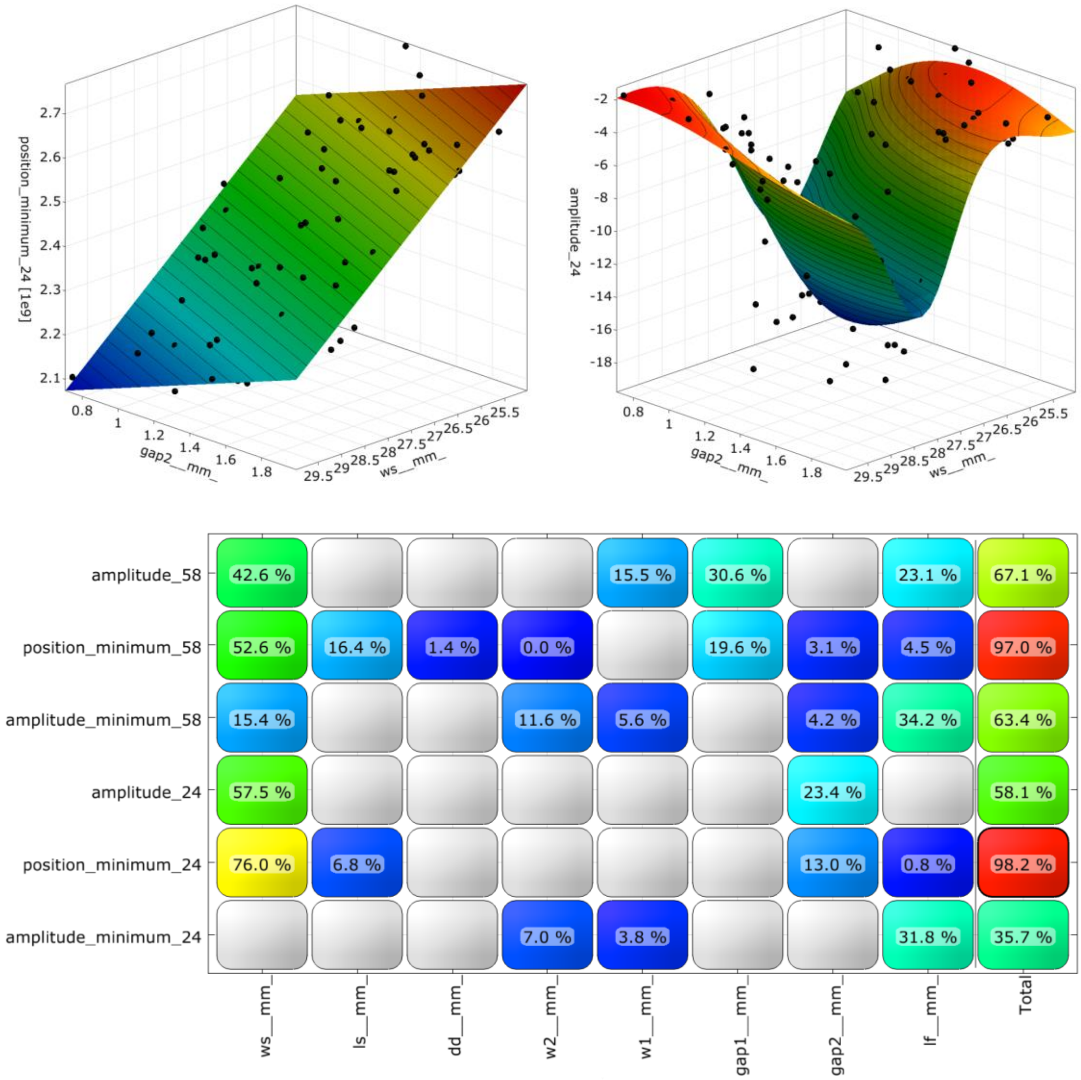

Figure 2: Optimal surrogate models for the position of the lower minimum (upper left side) and the corresponding amplitude (upper right side) and the variable sensitivities obtained by the Metamodel of Optimal Prognosis

It can be clearly seen in the last column of the sensitivity matrix, that the positions of the minima can be explained much better as the amplitude values. Therefore, as optimization strategy the positions of the minima were adjusted to the desired frequencies in a first step. Based on the DOE samples and the optimal surrogate models a fast gradient-based search could be performed to find a geometry parameter set, which results in a good agreement with the desired frequencies as shown in Fig. 3. Based on this pre-optimized design an Adaptive Response Surface Method was applied in a second step, in order to minimize the amplitude values of both minima in the return loss function while keeping the deviation from the desired frequencies as small as possible. In Fig. 3 the return loss spectrum of the optimal design is shown. The figure indicates an excellent agreement of the desired frequencies and a significant decrease of the return loss at 2.4 and 5.8 kHz. Comparing the optimal design with the initial one, we could summarize, that a significant reduced energy consumption of the antenna could be achieved and a much better agreement with the desired transmission frequencies was possible.

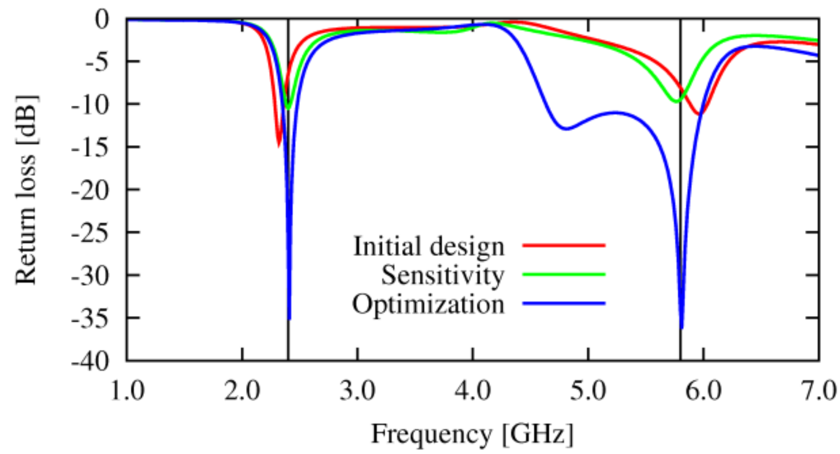

Figure 3: Return loss frequency spectrum of the initial and optimized design of the investigated dual band antenna

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