Multi-objective optimization for antenna design

The problem described consists of the optimization of a seven element antenna array in order to improve the radiating performance.
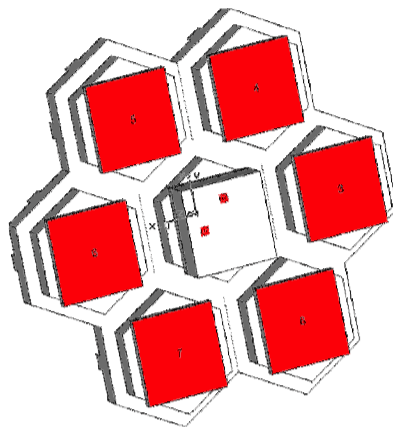
The aim of this work is to test the effectiveness of native, true multi-objective optimization techniques, available today in modeFRONTIER4®, a ready-to-use multi-objective environment, directly driving CST MWS, and taking advantage of some useful interactive postprocessing tools.

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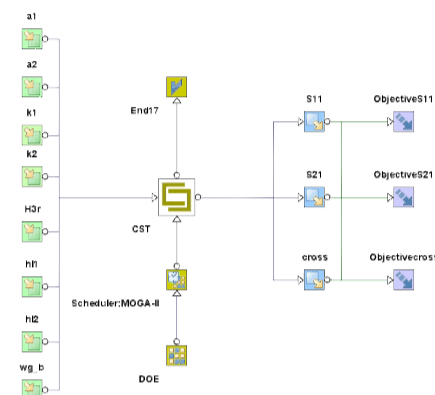
Problem description

The model is a representative element of an L band feedarray which is a part of an unfurlable array fed reflector antenna typically used for Mobile Satellite Services.

In the optimization of the feed element we have changed the geometrical parameters of the input section, including the cavity and patch dimensions, and the position of the patch within the cavity.

Model, Parameterisation Strategies and Targets

In this study, we considered eight geometric parameters. It was decided to set 3 different objectives:
1. Minimization of the Return Loss for each of the two ports;
2. Minimization of the electromagnetic coupling between ports;
3. Minimization of the cross-polarization component.

Numerical techniques used in the 3D EM CST MWS code employed

CST MICROWAVE STUDIO® (CST MWS) is a tool for simulation of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Besides the time domain simulator, which uses proprietary PERFECT BOUNDARY APPROXIMATION (PBA®) technology, CST MWS offers frequency domain on hexahedral and tetrahedral meshes, an Integral Equation solver for large structures, and a fast s-parameter solver dedicated to highly resonant structures.
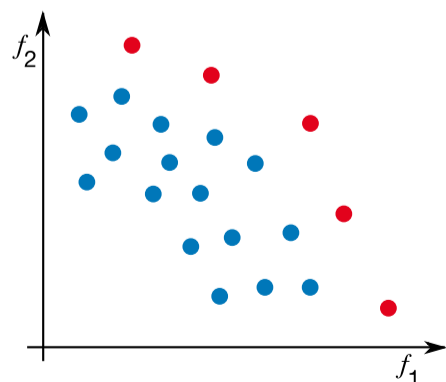
Multi-objective Optimization concepts and Pareto Frontier

In multi-objective a given number of functions have to be simultaneously maximized or minimized.

Hence, in multi-objective optimization, the concept of best design is replaced with the concept of dominant design.

Pareto dominance:

$$A >_p B \Leftrightarrow (\forall_i f_i(A) \geq f_i(B)) \cap (\exists_j : f_j(A) > f_j(B))$$

Optimization Setup

Before running the optimization the antenna model is integrated in the selected optimization environment, modeFRONTIER4®. Every single design configuration is evaluated in batch mode in order to let the optimizer work without human intervention and fully exploit the advantages of the optimization algorithms.

Since the optimization tool provides a direct interface to the CST MICROWAVE STUDIO® model, the optimization variables are directly linked to the antenna parameters and the analysis results are extracted and linked to the optimization targets.


Chosen Optimization strategy: MOGT & MOGA-II

Since the response of the system to the modifications of the free parameters is unknown, a two-phase optimization is carried out. In the first phase Multi-Objective Game Theory (MOGT) is used in order to have a fast mapping of the three dimensional Pareto frontier.
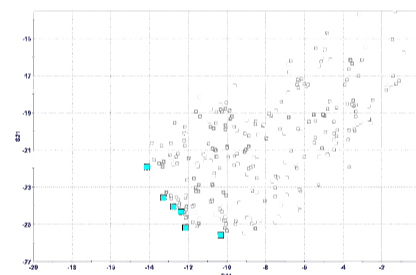
In the second phase a Multi-Objective Genetic Algorithm (MOGA II) refines the Pareto frontier exploration starting from some selected points of the first optimization run.
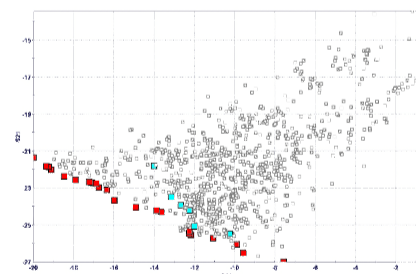
Conclusion

• Once the integration of the model in the optimization environment is done, all the optimization capabilities can be applied to improve the performance of the antenna.

• The optimization is a full batch process.

• Today's multi-core PCs and clusters are able to carry out multi-objectives optimization of a complex model by a reasonable computational time.

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