A Useful Tool for Analysis and Visualization of Grid Search Simulation Results

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The paper describes a software tool for quick analysis of results calculated by the *QuickWave-3D* electromagnetic simulator running in the Grid Search mode. In the Grid Search mode, results of EM simulations are displayed versus two or more geometrical parameters adopting predefined discrete values from a given range. In that regime, usually many data files are generated (i.e. scattering parameters file for each simulated scenario), which are difficult to browse and analyze in the domain of simulation variables (i.e. reflection coefficient of the microwave oven as a function of a load movement). Dependence of obtained results on simulation parameters can be useful for microwave designers as well as for teaching purposes. Two practical examples of application of the new program have been presented.

Introduction

In the field of microwave power engineering we frequently face the problem that the electromagnetic field is dependent on input variables in a complicated manner. In most practical cases, analytical solutions are not available and we have to use electromagnetic (EM) simulators. The typical aim of an engineer is to find an optimal solution, and for this reason, application of an optimization algorithm jointly with the EM simulator seems a straightforward approach. That approach, however, may not work very well in practical applications. The EM simulations are quite time consuming, and thus we need to use an optimization algorithm with a relatively small number of calculations of the goal function.

Moreover, the obtained results of EM simulations have limited accuracy and thus we can consider them as quite noisy. Under such circumstances the gradient optimization schemes usually fail. If we now add to the requirements the need to obtain the global and not the local optimum, it becomes quite clear that we are facing a difficult problem. It may become somewhat less difficult when we have initial estimation of the character of the optimized function and can find a good starting point for optimization (which is relatively close to the global optimum). Therefore, it is wise to make a regular coarse browsing of the whole domain (we call it Grid Search), and to manually choose the most promising region on which to limit the domain for the automatic optimizer.

On the other hand, there are also many situations where analytical solutions are already very well known, but for beginners (i.e., students) the relation between their input and results might be not clear at first glance. To help them to understand the problem, the teacher can prepare some Grid Search scenarios, which will visualize the dependence of results on each parameter. Those are the main areas where our tool can help the engineer. After several Grid Search simulations we get tens or hundreds data files (i.e., *S*-parameters), which should be wisely browsed or post-processed to extract useful information. Even if those are not very sophisticated operations, usually the main practical problem is how to process that great amount of data, and then to intelligently draw charts.
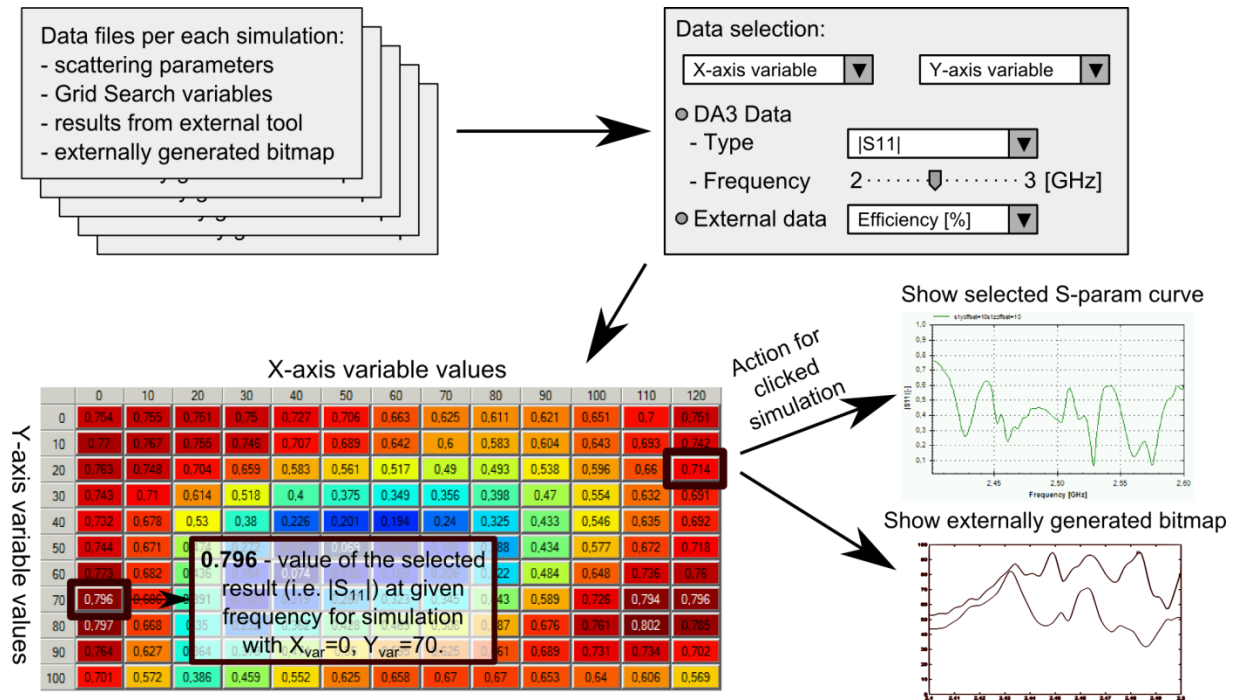
Fig. 1. Program concept overview.

The DA3 Viewer Program

The main aim of the program is to visualize data returned by the *QuickWave-3D* electromagnetic simulator [1] and/or external post-processing scripts on a colorful two-dimensional chart. The general advantage of the program in comparison to other tools delivered with the simulator is presentation of the data as a function of Grid Search parameters domain. It enables the user to have a quick look at the dependence of results on values of simulation parameters. The data set of each simulation can consist of four files:

- Scattering parameters file (*.da3) (whence comes the program name)
- Grid Search variable values (*.udp)
- Results calculated by external tools (*.res) [optional]
- Externally generated bitmap (several typical types like *.bmp or *.png) [optional]

This shows that even with a relatively small Grid Search domain, many files need to be processed (i.e., 10 values of 2 parameters results in 100 simulations, which may consist of 400 files) – and this is done by the DA3 Viewer at once.

The structure of the data flow is presented in Fig. 1. The user can associate the Grid Search variables with the X and Y axes of the 2D chart, where results will be presented. In the next step a selection between *QuickWave*'s *.da3 and external files needs to be done. In the first case, the user should choose the name of parameter to be shown (i.e. modulus of the reflection coefficient $|S_{11}|$) and the frequency. In the case of externally generated data, the user can choose just a single variable to show. Selected data is presented on a grid as numerical values and a color map. Moreover, when a cell on the grid is clicked, the chosen scattering parameter curve as well as the externally generated bitmap associated with that simulation is presented in the main window of the program.

40

Object	Material	Length (*x*-dir) [mm]	Width (*y*-dir) [mm]	Height (*z*-dir) [mm]
Cavity	air	226	270	188
Waveguide	air	18	78	80
Shelf	glass	diam.=215	diam.=215	6
Load	load	30	30	40

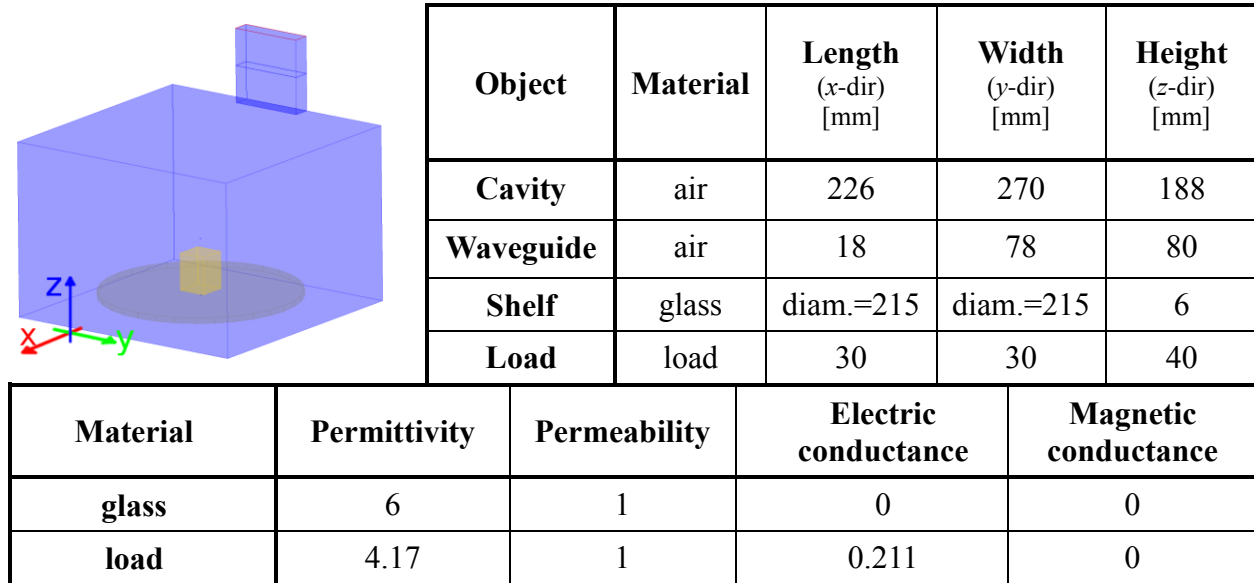| Material	Permittivity	Permeability	Electric conductance	Magnetic conductance
glass	6	1	0	0
load	4.17	1	0.211	0

Fig. 2. Microwave oven scenario overview – 3D sketch and parameters.

Results

Several possible applications for this tool can be imagined. The program was initially created and optimized to support the design of a solid-state microwave oven for the HEECS project (High Efficiency Electronics Cooking Systems) [2]. One of the tasks was to observe and optimize the efficiency of the microwave energy injection into the cavity as a function of the feeding waveguide aperture position. Simulations were performed with *QuickWave-3D* in the Grid Search regime and the efficiency was calculated by an external Matlab script. Color maps with best efficiency available for all scanned waveguide positions have been generated [3, 4].

An even simpler example can be proposed with a single aperture microwave oven. The scenario consists of a rectangular cavity that contains a fixed glass shelf and a cubical lossy load moving on the surface of the glass shelf. The scenario overview and parameters are presented in Fig. 2. Several questions about that simple scenario might be:
- How does the input reflection coefficient changed when the load is moving, and the frequency of operation is fixed?
- How much can the reflection be reduced in the previous scenario by a smart choice of the frequency?
- What are the frequencies at which minimal reflection occurs?

Answers to all those questions can be quickly acquired using the DA3 Viewer and some simple external scripting. A MATLAB script is used to find the frequency with lowest reflection. Main results are presented in Fig. 3. After performing all simulations performed (usually this is the most time consuming operation), all the post-processing actions can be done in just a few seconds.

Another example is design of a rectangular patch antenna. In this case, again, several interesting antenna parameters like input impedance, bandwidth, resonance frequency and radiation pattern are highly dependent on several variables – patch dimensions, dielectric permittivity and thickness, feeding point position, etc. The last one has been chosen for this
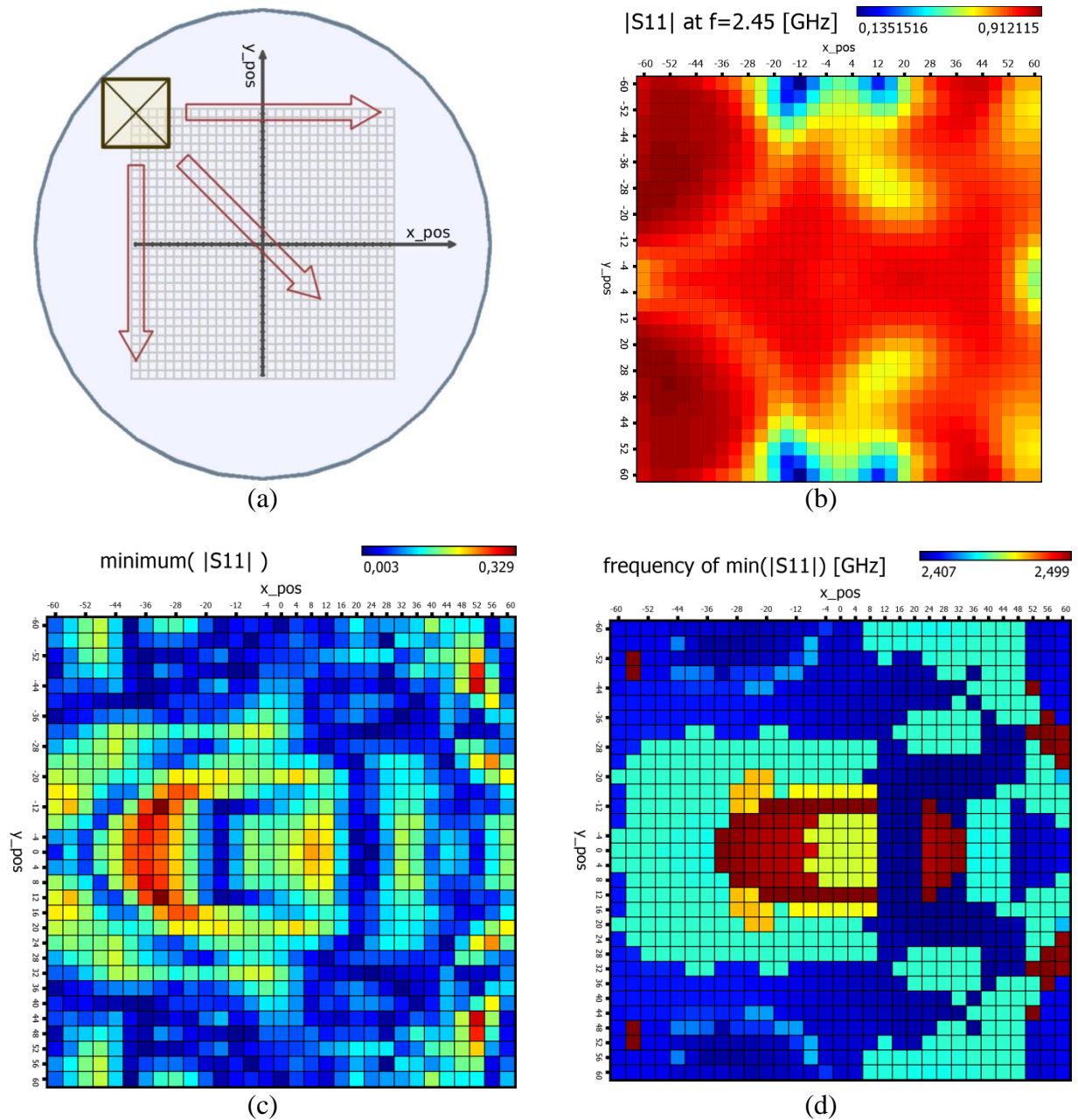
Fig. 3. Microwave oven scenario: (a) sketch of the load which is moving on the top surface of the glass plate; results: (b) reflection coefficient at 2.45 GHz (fixed frequency), (c) minimum available reflection coefficient between 2.4 and 2.5 GHz (frequency tuning), (d) frequency at which minimum reflection occurs.

example due to simplicity of result interpretation (positions on the plot are directly related to position on the patch), as seen in Fig. 4.

This example shows how the program can be used for teaching purposes. The presented antenna consists of a rectangular patch that exhibits two main resonances, closely placed in the frequency domain, along X and Y axes. Figures 4(c) and 4(d) can be used to support the
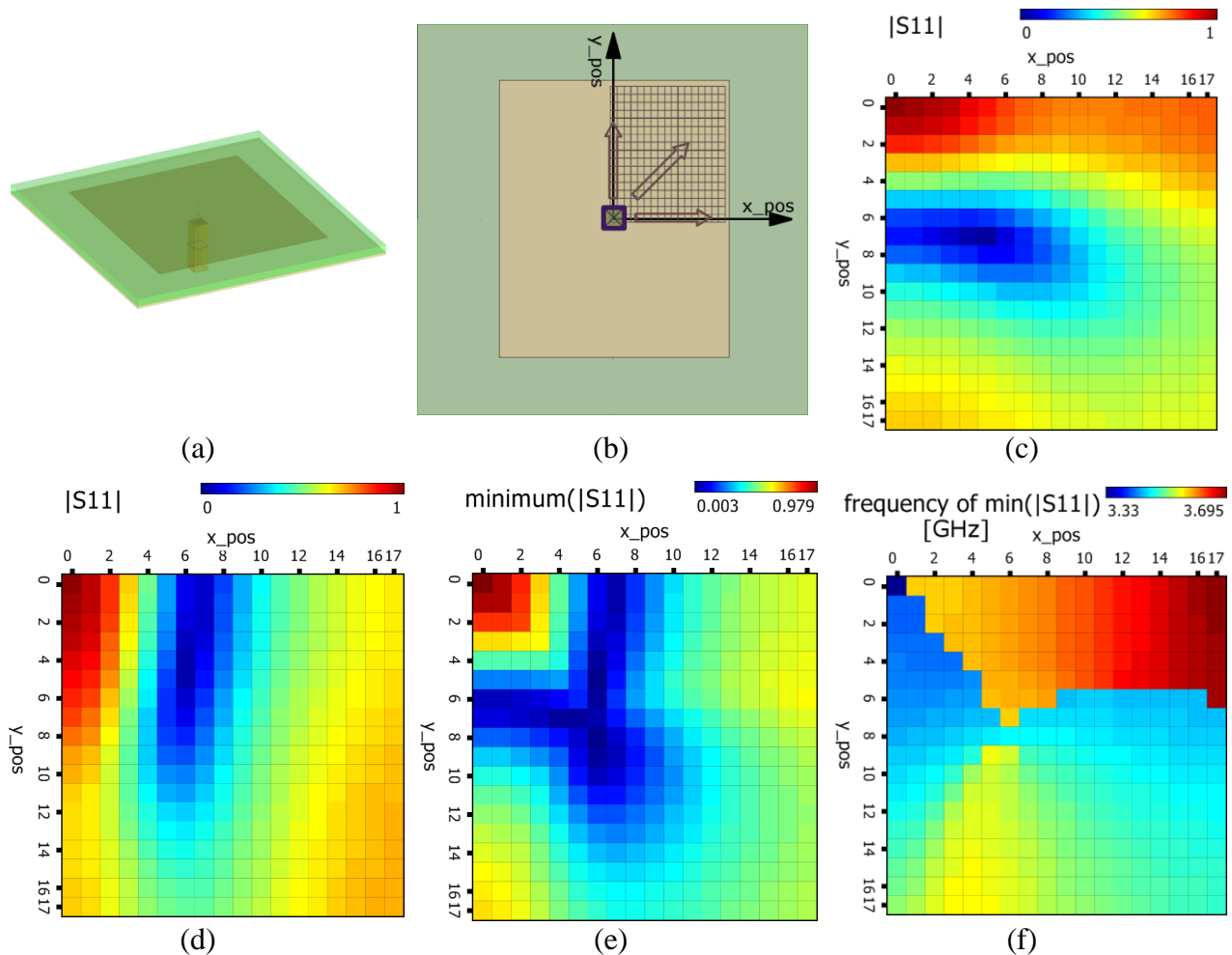
Fig. 4. Patch antenna scenario: (a) general overview, (b) sketch of the analyzed feeding point positions; results: (c) $|S_{11}|$ at frequency 3,44 GHz, (d) $|S_{11}|$ at frequency 3,59 GHz, (e) minimum of $|S_{11}|$ in the whole considered band (3…4 GHz), (f) frequency of minimum $|S_{11}|$.

explanation to students of the practical relation between feeding point position and impedance matching for a specific frequency. The area where good matching is easily available, and the way in which the resonant frequencies are affected by the feeding point positions have been presented in Figs. 4(e) and 4(f) respectively.

Conclusion

The DA3 Viewer is relatively simple, yet exhibits a high potential for utility for engineers as well as academic teachers. Easy-to-handle user interface helps in quick preparation of quality reports and esthetic presentations. The tool is under continuous development and new features are being implemented, so all ideas and critical comments are welcome.

Acknowledgment

References

[1] *QuickWave-3D* – Software for Electromagnetic Design, http://www.qwed.eu/.

[2] High Efficiency Electronic Cooking System, http://www.heecs.eu/.

[3] P. Korpas, A. Wieckowski, M. Krysicki, M. Celuch, and F. Bressan, Application study of new solid-state high-power microwave sources for efficiency improvement of commercial domestic ovens, *Proc. 47th IMPI Annual Microwave Power Symp., Providence, RI, June 2013* (to be published).

[4] A. Więckowski, P. Korpas, M. Krysicki, F. Dughiero, M. Bullo, F. Bressan, and C. Fager, Efficiency optimization for phase controlled multi-source microwave oven, *Proc. Intern. Conf. on Heating by Electromag. Sources (HES-13), Padua, Italy, May 2013* (to be published).