In this paper, a modular approach using the System Assembly and Modeling (SAM) of CST Studio Suite® is used to optimize a reflector antenna system in a piecewise manner. The results are compared to a full system simulation. It is shown that a similar accuracy to that of the full system simulation can be attained with the modular approach, with a much shorter simulation time and using less computational resources.

Today increasingly complex systems can be simulated with 3D electromagnetic solver technology, especially given the recent improvements in software and hardware. The problem is that these models can be quite large and cumbersome to deal with. Systems typically consist of several components, which are designed and optimized separately before being combined to form a system. Depending on the structure and physical operating mechanism of the device, certain numerical methods or solvers, combined with a suitable meshing strategy, might lead you to an accurate answer more quickly than others. Thus the possibility to easily change solver technologies or even compare them for the same design is an advantage.

Simulation complexity also depends on the design stage: Are you currently doing component design, studying component interaction, or optimizing the complete system? This affects the model size and the resources that are required to successfully run the simulation.

This paper demonstrates the use of the System Assembly and Modeling (SAM) in CST Studio Suite which allows the user to easily construct and combine models made of many different parts.

The specific application that is discussed in this paper is a workflow to optimize a reflector antenna system, but without actually simulating the complete model. Instead, the problem is split into smaller parts and the new functionality introduced by the SAM is used to combine and to optimize the results.

**DESIGN STATEMENT AND GOALS**

The goal is to design, simulate and optimize a reflector antenna system for a wide frequency band (Figure 1). In this case, the chosen frequency range is from 10 to 20 GHz. The system should have a minimum of 30dB gain over the full band with a circularly polarized far field. The
application for this type of system could be, for example, a satellite ground station.

The largest component in the system is the parabolic reflector dish with an offset feed. The feed antenna system is quite large and could potentially shadow the dish so center feed is not optimal. The purpose of this design is to move the feed structure out of the beam path so that it doesn’t block the beam. This type of arrangement is typical for small parabolic reflectors, such as those found in home television satellite receivers, which are small enough that the feed structure would otherwise block a significant percentage of the signal.

A feeding antenna is naturally required to excite the reflector. Horn antennas are often used for this purpose, since they are highly directional and can work over a wide frequency band efficiently. They are often symmetric, so can be used for circular polarization, although that usually requires a specific input feed. It is thus necessary to design a feeding network which is built into the chassis of the horn antenna. Lastly, the feed structure also requires supports to keep it in place above the reflector.

In the end, there are a large number of individual components which can all be simulated and optimized separately. However, keeping track of a large number of files and different versions can quickly become very cumbersome. Optimizing the complete system in a piecewise manner is also difficult, since the results from many different files and simulations have to be combined.

SRM can help us by automatically keeping all the individual components up-to-date and by providing a method to automatically optimize the complete structure while still simulating only smaller parts of the system.

DESIGNING THE ANTENNA SYSTEM

To quickly find a suitable feeding antenna and a reflector dish, Antenna Magus is an irreplaceable tool as it has a searchable database of over 330 antennas. In addition to exploring the antenna database, users can also design the antenna parameters for the specified criteria, see estimated performance graphs, vary the physical parameters to create further tweaks, and finally export the design as a fully parameterized CST Studio Suite model. Further utilities also include array synthesis, substrate and waveguide libraries, and custom antenna templates from imported reference files. For this particular system, a corrugated horn antenna from Antenna Magus was chosen (Figure 2).

Similarly, Antenna Magus can be used for the initial design of the parabolic reflector antenna and for optimizing its size to get minimum 30dB gain, as stated in the project goals. After quickly verifying the proposed designs, they can both be easily exported as fully parameterized CST Studio Suite models, ready to be simulated.

For the feeding network, an orthomode transducer design from the literature is chosen, similar to what would be used by an engineer in the industry. The working principle of the transducer is that it has two input ports, which are connected via a series of waveguides to an output port, thus combining the linearly polarized modes in the inputs to a single circularly polarized one at the output. By optimizing the length of the waveguides connecting the ports, the phase difference between the modes can be manipulated, allowing one to control the polarization of the combined mode.

SYSTEM ASSEMBLY AND MODELING (SRM)

After the components are modeled and verified to work, the next step is to make sure that they all work together as they should and that they satisfy all the design criteria. The most straightforward option is to combine all the individual components into a single model and run the complete simulation in a single simulation. However, for large and complex systems this is not the most efficient approach.

In this case, the reflector dish diameter alone is over 40 wavelengths at 20GHz. The smallest details of the feeding network are around 1mm which, together with the high frequency and the large scale of the structure, forces the number of cells in a volumetric hexahedral mesh to be almost 400 million. This is practically impossible to solve on a single system even with a large amount of memory since the required simulation time would be very long. Optimizing such a system would be very slow.

It is possible to use cluster computing in combination with hardware acceleration to solve the full system in a reasonable time. This particular example without the feeding network took almost four hours (3h 50 min) on a four node cluster system with hardware acceleration (2 Tesla C1060 GPU cards on each node).

Instead of running a complete system simulation, splitting the simulation into smaller parts is a much more feasible approach. It allows us to optimize each part separately using the frequency domain solver for each simulation and to combine smaller, faster simulations so that the total time used for them is shorter than for a single but very large model. This also makes complete system optimization more efficient.

SIMULATION SETUP WITH SRM

The first step in setting up the SRM simulation is to import all the individual component designs into a new CST Studio Suite project. The required components must be first designed separately as parameterized models. Any changes that are made in the original model files can be updated to
the System Assembly Model. It is thus possible to modify the imported models even after the import, as the system looks up the updated information from the original files.

The next step is to build a schematic representation of the imported models to define the electrical connections between the ports of the components, in other words, a circuit representation of the model. The schematic representation can be used directly for circuit simulations or for automatic alignment of the components in the 3D layout. The layout view of the system is a three-dimensional view where the components can be positioned in the correct locations. The snapping tool can use the schematic port connection information to semi-automatically align the components with minimal user input.

Based on the schematic and the three-dimensional layout it is possible to generate new simulation projects with any combination of the imported models. A simulation project is simply a CST Studio Suite model that is stored locally within the master file. The user thus does not need to keep track of multiple file versions or component combinations, as the data as well as the simulation results are stored in a single file. All parameter changes in the master model are automatically updated across all the generated simulation projects.

For the reflector antenna system one could thus first build a model for the feeding network, then simulate and optimize it using frequency domain solver. The feeding network results can be used in circuit form and applied to the horn antenna in the schematic, i.e. at the circuit level. The feeding network model for the feeding network, then simulate and optimize it using frequency domain solver. The feeding network results can be used in circuit form and applied to the horn antenna in the schematic, i.e. at the circuit level. The feeding network results can be used in circuit form and applied to the horn antenna in the schematic, i.e. at the circuit level.

Since it is possible to run all simulation projects from a single place where the results can also be directly accessed, it is also possible to automate the complete system optimization using the individual simulation projects. The optimization could for example consist of the following steps:

1. As the feeding network is independent of the horn and reflector antenna simulation, it can be optimized as a separate project. After that is done, its S-parameter results can be used directly to create a feeding network for the horn antenna in the schematic, i.e. at the circuit level.
2. Next, an optimization loop for the horn antenna and the reflector is created. Any variable value change is automatically updated to the corresponding model file when the antenna and feeding network simulation is run.
3. The far field of the horn antenna is exported automatically via a post-processing template and imported as a source in the reflector dish model, which is automatically run. The resulting far field is automatically evaluated via post processing templates and used as the optimization goal value.

The original goal was to optimize the complete reflector antenna system gain and far field ellipticity, so that the minimum gain is at least 30dB over the full frequency band and the far field is circularly polarized.

For optimizing gain, Antenna Magus helpfully provides the user with design hints about what parameters to change in order to achieve a certain effect. For example, changing either the horn antenna flare length or diameter will affect the gain. To optimize the ellipticity, the phase difference between the two combined input modes can be modified, or the horn antenna ellipticity can be changed directly.

As the initial results for the ellipticity already approximately fulfilled the design statement, the main goal was to optimize the gain using the flare length and the diameter of the horn antenna as variables. The optimization converged after only four iterations and the gain was improved by about 2dB over the full frequency band. The gain at the lower end increased over the 30dB minimum level so the design specifications were met. The flare diameter could still be increased for even higher gain. The size of the reflector could also be increased, which would have the same effect.

The total simulation time for the optimization of the system assembly model was one hour and 49 minutes using a single workstation with hardware acceleration. By comparison, the same optimization process with the complete model took three hours and 48 minutes on a four-node cluster system with hardware acceleration on each node. The time savings of the split simulation approach are thus considerable.

CONCLUSION

System Assembly and Modelling (SAM) is a real leap forward for complex system simulations and optimizations. The advantages are numerous. All individual components can be imported into a single master file, which can then be used to automatically keep track of all the changes. Any combination of the components and solver technologies can be used to generate new simulation projects. The automatic feedback loop between the simulation projects allows you to easily optimize complex systems by changing a variable in one project and using the results from another as the goal value.

In short, SAM is a new way of working with the software to automatically leverage the already existing functionality in CST Studio Suite to split the simulations into smaller, more efficient parts, which can be simulated faster and with less resources than the complete system while still retaining the same accuracy.

REFERENCE


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