Advances in Commercial Software for High-Gain Antennas and Electrically Large Platforms

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***Abstract*—We present the latest enhancements in the GRASP software package for analysis and design of electrically large antennas and platforms. The focus is on the hybridisation of efficient and accurate methods which allows antenna systems with very high complexity to be analysed and optimised, e.g., an end-to-end model of a multibeam reflector antenna with a complex feed cluster consisting of 19 feed horns, each with integrated waveguide OMTs and power combiners. The time per iteration is measured in seconds, despite the large electrical size of the reflector, the complexity of the feed cluster, and the high number of individual beams. Finally, we illustrate that a moderately priced dual-CPU workstation is sufficient for performing a full-wave analysis of a detailed model of a telecommunication satellite at Q band, where the satellite measures thousands of wavelengths.**

I. Introduction

High-gain, high-performance antennas are typically realised as a single- or dual-reflector configuration, due to the low losses and low mass in comparison to direct radiating arrays with equivalent aperture size. The industry standard for RF analysis of large reflector antennas is the software package GRASP, in particular for the most demanding applications, e.g., antennas for space applications. In this paper, we present two new capabilities in GRASP that allow larger and more complex antenna systems to be analysed and optimised. The two capabilities are i) combined optimisation of large reflectors and associated feed chains, and ii) full-wave modelling of electrically large platforms using a recently introduced in-core CAD file geometry input.

II. Combined Optimisation of Large Reflectors and Feed Chains

The RF performance of large reflector antennas is typically analysed using GRASP, whereas the associated feed chain is typically designed by a separate software tool tailored to optimization of feed horns and waveguide components. This multi-tool design approach is somewhat tedious and to make things worse, it results in sub-optimal designs because intermediate optimization goals must be introduced in the feed and waveguide component design tool, although these goals are not design goals of the combined feed/reflector antenna system. Typical intermediate goals are the feed taper and feed phase centre. The drawbacks of the multi-tool design approach

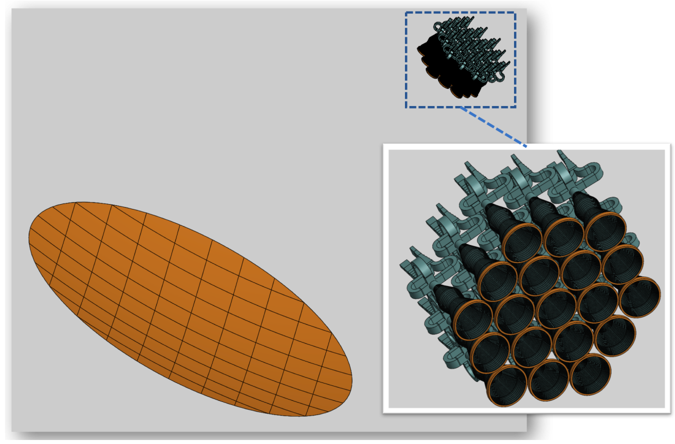

Fig. 1. Multi-beam reflector system incorporating a feed cluster with 19 feeds. Each feed includes a turnstile OMT, power combiners, and multiple waveguide bends. The inset shows a close-up of the feed cluster that includes three different feed geometries.

will be eliminated by integrating a fast and accurate tool for feed and waveguide component analysis in GRASP. This enables a single-tool design process where the entire antenna system, i.e., all reflectors, waveguide components, and feeds, can be analysed and optimized as a single model, but using multiple hybridized methods. With this tool available, the need for intermediate optimization goals is no longer present. Instead, a *direct* optimization technique can be used, where the influence of all geometrical changes are only measured on the performance parameters that matter, e.g., the *secondary* pattern, or the return loss before all waveguide components in the feed chain.

The new hybridized tool will have the following characteristics:

1) A Generalized Scattering Matrix (GSM) technique is used to decompose the problem into smaller regions, each solvable with an efficient method suitable for the specific subproblem.
2) A range of full-wave analysis techniques have been incorporated for waveguide components and feeds, including the Higher-Order MoM [1], various Mode Matching methods, e.g., [2], [3]. PO/PTD is used on large reflectors.

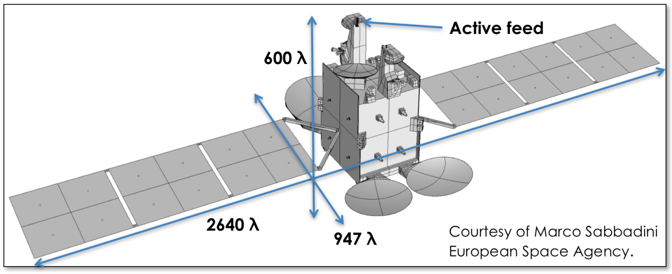

Fig. 2. Detailed CAD model of telecommunication satellite to be analysed with Higher-Order MLFMM at Q-band (40 GHz).

3) A component-based approach based on a predefined library simplifies the model definition. Further, the same component may be reused several times in the same model, providing huge savings for typical feed chains.

The capabilities of the new software are illustrated with a single-feed-per-beam multi-beam reflector problem which are commonly used on High Throughput Satellites. The selected configuration is shown in Fig. 1 where a feed cluster of 19 feeds are illuminating a 1.2 m reflector corresponding to 80λ at 20 GHz. The feed cluster uses three different kinds of feeds, one feed at the centre, 6 feeds in the ring around the centre feed, and 12 feed in the outer ring. The geometry parameters of the horns are optimized and optimization goals are defined on secondary pattern and on the return loss of the feed chain. The software allows for optimizing the patterns of the individual beams, as well as the C/I quantity, i.e., the interference of a beam from all other beams. The initial analysis of the antenna system can be performed in 26 seconds on a laptop computer, including the full-wave analysis of all feeds and the waveguide components in the feed chain, as well as the radiation pattern evaluation of all 19 beams. The average time needed for repeated evaluations during the horn optimization is significantly shorter, as can be observed in Table I.

TABLE I
LAPTOP COMPUTATION TIME PER FREQUENCY FOR A 80λ MULTIBEAM REFLECTOR WITH COMPLEX FEED CHAIN.

	All beams	Per beam
Initial computation time	26 s	1.4 s
Average computation time during optimization	4.7 s	0.2 s

III. FULL-WAVE MODELLING OF ELECTRICALLY LARGE PLATFORMS

Accurate assessment of platform interactions and antenna interference requires an efficient full-wave tool capable of handling electrically huge problems. GRASP's Higher-Order MLFMM solver [4] offers a very low memory footprint in comparison to competing solvers, in particular for analysis of large platforms. The MLFMM solver in GRASP has now been extended with an in-core direct CAD file input - the internal meshing algorithm then automatically computes a high-quality mesh consisting of curved quads up to 4th order, i.e., 25 interpolation nodes per patch, which results in high surface accuracy even for patches up to $2\lambda \times 2\lambda$.

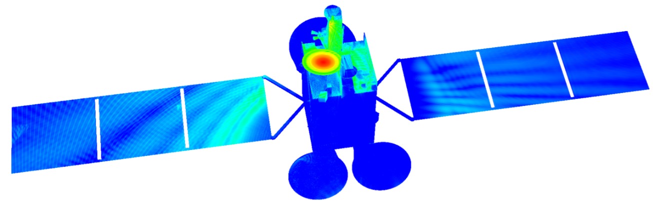

Fig. 3. Currents on the satellite platform computed with Higher-Order MLFMM at Q-band (40 GHz).

The capabilities of the higher-order MLFMM solver are exemplified with a very challenging platform scattering problem: A detailed model of full-size telecommunication satellite, measuring 2640 wavelengths at Q-band (40 GHz) as illustrated in Fig. 2. Such high frequencies were until recently only used for scientific purposes, but the Q/V band will be used extensively for satellite communication in the future, due to the congested spectrum at Ku and Ka-bands. This move towards higher frequencies is a significant challenge for the software tools used to analyse the platform scattering. The higher-order MLFMM in GRASP has been used to analyse the CAD file shown in Fig. 2 in the case where the active feed is located on the top deck of the spacecraft. The computed currents are shown in Fig. 3 and the details of the discretization are listed in Table II. It can be observed that full-wave simulations of a full-size telecommunication satellite at Q-band can be performed on a moderately priced dual-Xeon workstation.

TABLE II
DETAILS OF THE HIGHER-ORDER MLFMM SOLUTION

Frequency	40 GHz
Electrical size	1,863,702 λ^2
Higher-order unknowns	30,793,904
Equivalent RWG unknowns	150,000,000
Iterations (0.001 residual)	85
Runtime, dual Xeon @ 2.6 GHz	12:30 hrs
Memory	720 GB

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