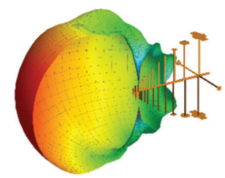
TECHNICAL DOCUMENT

OPTIMIZING ANTENNAS INSTALLED PERFORMANCE

Efficient and accurate modeling of antennas and their installed performance on defense and aerospace platforms can significantly reduce the time and cost needed for their design and installation.

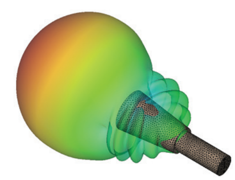
Overview

For problems of electromagnetic modelling and simulation, Altair provides Feko. Altair® Feko® has been a leader in high-frequency electromagnetic simulation for over 20 years. It is the leading tool for antenna design, antenna placement and coupling, virtual test drives and flights, EMC, radio frequency interference, radar and radio coverage and planning, and spectrum management.



Wire antennas

This document looks at how Feko—in conjunction with Altair's solutions for design simulation, exploration and optimization, structural assessment, and thermal analysis—can help antenna designers develop and verify their antenna solutions quickly, accurately, and efficiently. It will focus on how to realize automated, iterative design optimization through modelling and visualization.

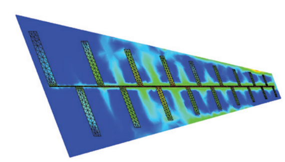


Reflectors and horns

Antenna Design

Designing and installing antennas for optimum performance on air, space and land vehicles requires taking into account not only the characteristics of the antenna itself, but also of the antenna's environment. The latter necessarily includes the geometry of the platform and the geometry and materials of the radome, if one is used. In the case of low-flying aircraft like drones and helicopters, the terrain over which they fly may also need to be accounted for.

Feko helps engineers quickly and accurately simulate a wide range of antennas and analyze their performance in highly accurate simulations of aerospace and defense platforms and their working environments.



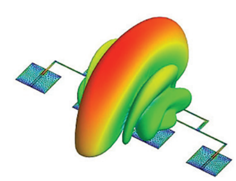
Wideband antennas

The technology stack provides a unique solution combining installed antenna performance with wireless coverage analysis. Its hybridized and parallelized solvers permit customers to efficiently analyze complex and electrically large problems. Feko also includes fast and accurate wave propagation models for all scenarios—from indoor, through urban and rural, to nationwide.

Antenna Design and Analysis

Feko's accurate and efficient full-wave and asymptotic solvers allow engineers to analyze many different classes of antennas including:

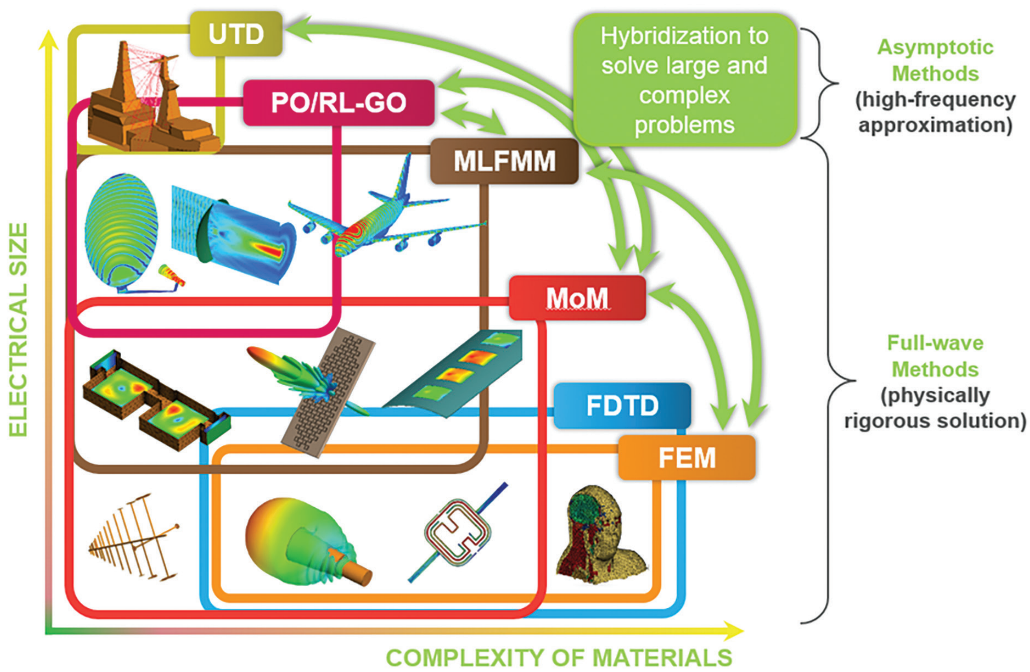
- Wire antennas
- Reflectors
- Horn antennas
- Wideband antennas
- Microstrip patch antenna arrays



Microstrip patch arrays

No single computational electromagnetic method can address every application. Therefore, Feko offers multiple solution methods. These include:

- Full-wave methods for problems with complex geometries and materials
- Asymptomatic methods for electrically large problems
- Hybrid methods for problems with both large-scale and complex scenarios



Antenna Design Workflow

The design workflow for any antenna starts from the antenna's required performance. Potential designs are identified and simulation models are built. The results from the simulation can then be used to interpret the antenna's fundamental operating principles.

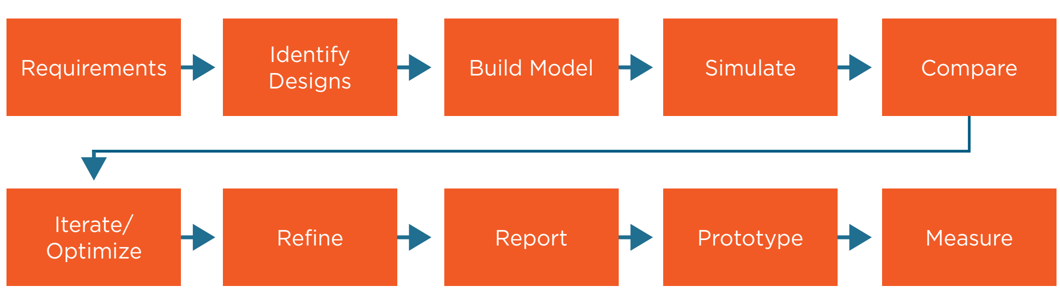
Comparing the simulation results to the required performance, and using the knowledge obtained regarding the operation of the antenna, the design can be optimized and refined to meet the requirements.

For the first step of identifying possible designs and for building initial models, Feko offers a series of parametric antenna models in the Component Library.

When designing a novel antenna, the engineer must find the optimum combination of the design variables that achieves the system requirements. This requires an understanding of the complex interactions between these design variables and how they affect the antenna's ability to reach the design objectives. Except in cases of very simple antenna geometries, attempting to combine these variables manually, based on experience or intuition alone, is unlikely to achieve an optimal design. In most cases, a more scientific approach is required.

Combining Altair's Feko and HyperStudy products, it is possible to realize automated optimization iterations with either model-based or data-based simulations for efficient machine learning and optimization of antenna designs.

Altair customers have access to both these products (and more than 150 others) through Altair Units, Altair's unified licensing system.



Find out more: **altairone.com**

Antenna Installed Performance

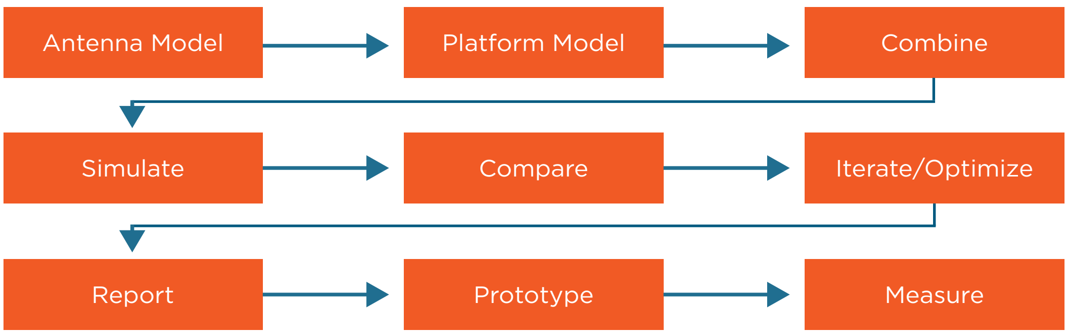
Altair Feko is widely used for antenna placement analysis. It is ideal for solving any type of electrical structure, including large platforms. The hybrid methods in Feko facilitate the analysis of geometrically complex details on large electrical platforms.

Feko allows engineers to accurately and efficiently account for the use of composite materials in their platforms and to consider the ever-increasing frequencies employed in modern communication systems. Combined with HyperStudy, Altair's Design of Experiments (DoE) and automated, iterative design optimization tool, Feko can also be used to consider not only antenna installed performance but also radiation hazard and other system performance parameters.

Installed Performance Workflow

The workflow for analyzing installed antenna performance begins with building the required antenna model and then a model of its platform. Then, once the antenna model is integrated with the platform model, the performance of the installed antenna can then be efficiently simulated by Feko.

Comparing the results of Feko's simulation with the desired performance, once can then adjust the design to optimize that performance.



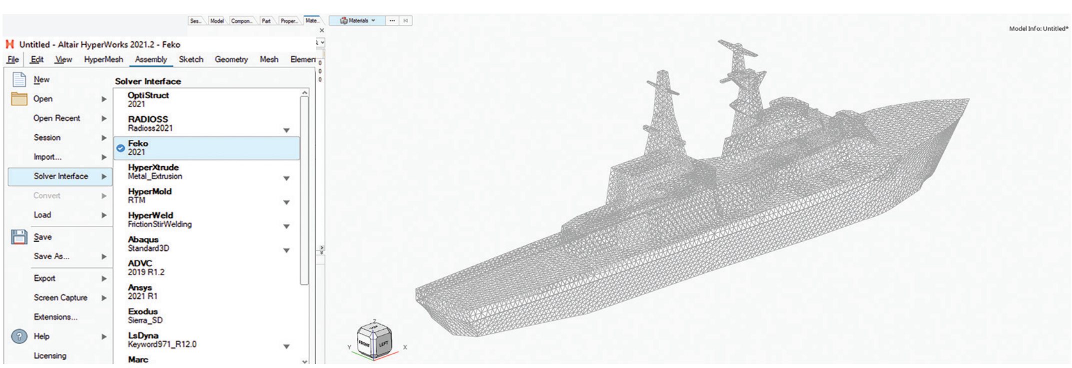
Platform Model Clean-up And Meshing with Altair HyperWorks

To analyze the combined CAD model of the antenna and platform, the model must first be meshed.

Meshing creates a tessellation of the CAD geometry that becomes the input to the Feko solver. Accurate simulations require a good quality mesh with correctly sized elements. Mesh elements that are too small—and therefore too many—tax the memory capacity of the solver and degrade performance. CAD models of poor quality or with unnecessarily high levels of detail will require clean-up.

While Feko comes with powerful CAD fixing tools (CADFEKO), HyperWorks is a specialized tool for model clean-up and mesh generation. It provides much faster model clean-up and meshing for very complex models and models with faulty parts and doesn't require any additional licensing, as it runs on Altair Units like the other Altair simulation products.

[To get an idea of the modeling capabilties watch our Feko playlist](#).



The dedicated Feko solver interface in HyperWorks simplifies the interaction between Feko and HyperWorks by:

- Only showing options relevant to antenna engineers
- Generating valid mesh elements for Feko's solvers
- Providing for definition and assignment of electromagnetic materials and properties

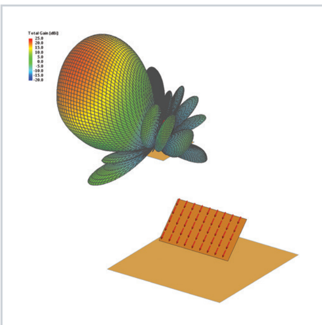
A dedicated file format (.fhm) allows for seamless interaction between Feko and HyperWorks.

Model Decomposition

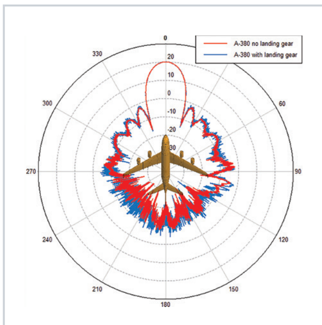
Model decomposition enables complex antenna models to be replaced by equivalent source and receiver representations. By reducing the complexity of the model and thus also reducing the mesh, the computational requirements of the simulation can be reduced significantly.

Feko provides three different sources to choose from, depending upon your application. These are:

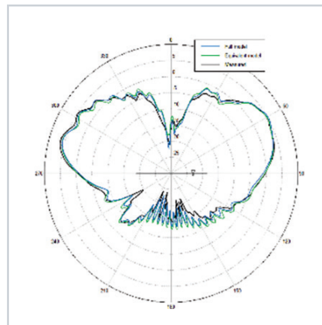
- Near field source
- Far field source
- Spherical mode source



4.5 GHz 9x5 element array and far field



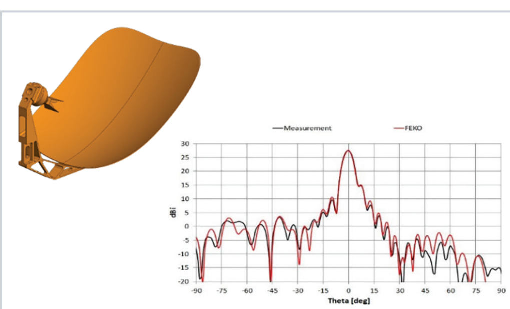
Far field pattern with and without landing gear using RL-GO and the spherical mode source



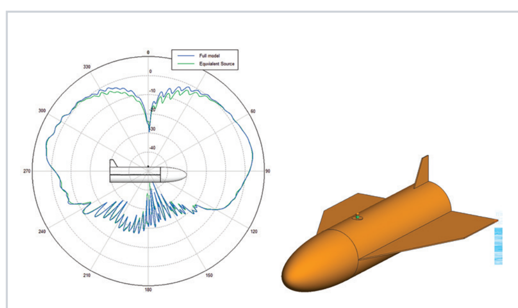
Monocone antenna

Similarly, these equivalent sources can be used as receiving antennas. Thus, Feko's models for ideal receiving antennas include:

- Near field receiving antenna
- Far field receiving antenna
- Spherical mode receiving antenna



Offset reflector antenna fed by the dual ridge



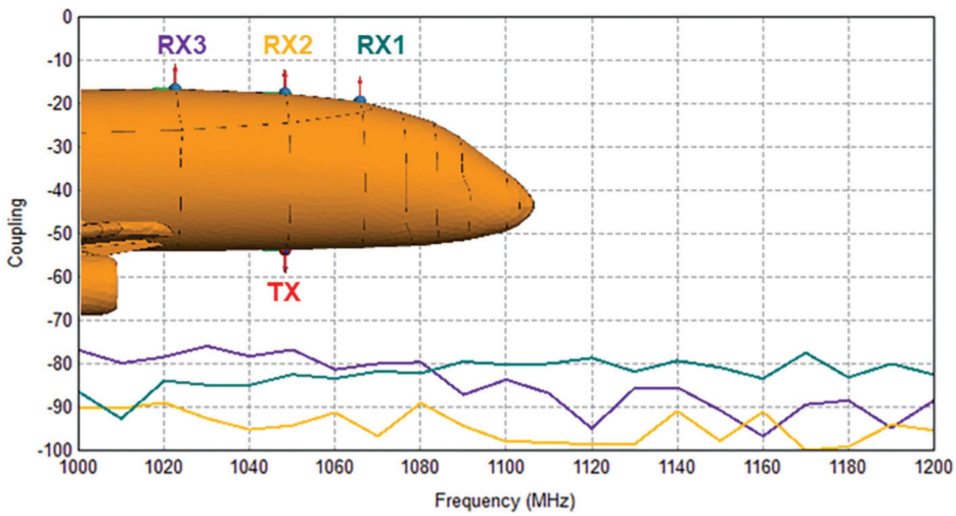
Space plane

The equivalent fields for these sources can obtained by importing measurements of physical antennas or by simulating antennas models in Feko. Supported measurement formats are provided by Microwave Vision Group (MVG).

Comparing the results of models that include the antenna geometry to those that use the equivalent field representation for the antenna (superimposed one over the other in different colors in the graphs shown here), one can see that the model decomposition approach produces highly accurate results. And it does so at a much lower computational cost compared to using the complex antenna geometry.

Antenna Coupling – Co-Site Interference Analysis

Model decomposition can also be used to simulate antenna coupling. With both the transmitting and receiving antennas represented by their far-field patterns, coupling is determined as the ratio of the received power to the transmitted power.



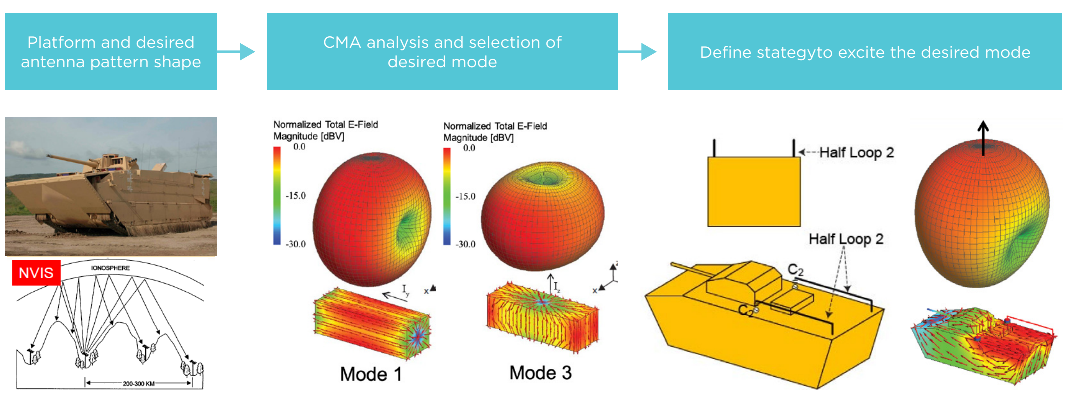
The coupling—10*log(RX_Power/TX_Power)—is estimated at the 3 different locations in the 1-1.2 GHz band. Antenna mismatch is not taken into account in this calculation.

In the example, equivalent far-field (ideal) receiver antennas are placed at 3 locations on top of an aircraft fuselage, while the transmitter is placed on the underside of fuselage. The same far field that was used for the source is also used for the receivers.

Characteristic Mode Analysis

Another Feko capability that can also be applied to the analysis of installed antenna performance is Characteristic Mode Analysis (CMA).

In the example for the Expeditionary Fighting Vehicle (EVF) shown below, the EVF's antennas are used to excite the radiating modes of the EVF platform using the platform as the main radiator. The CMA can identify these (platform) radiating modes and analyze how well certain antenna geometries and locations are able to excite these modes.

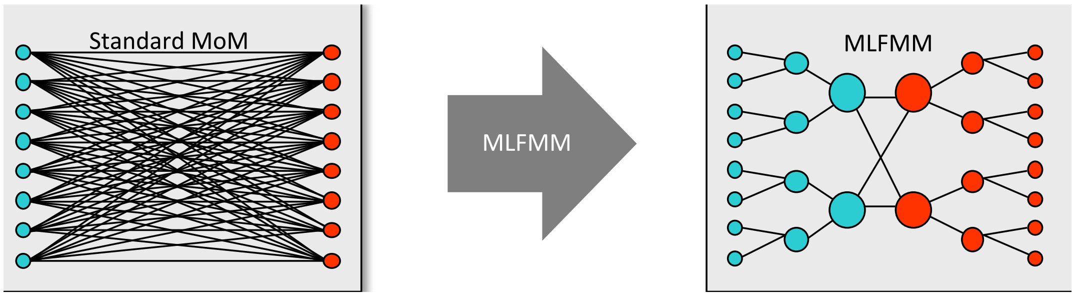


SIMULATION PERFORMANCE

Multi-Level Fast Multipole Method

Multi-Level Fast Multiple Method (MLFMM) allows for the efficient and accurate analysis of the installed performance of antennas on large platforms. The MLFMM is an alternative implementation of the Method of Moments (MoM), working with a factorized version of the matrix.

For electrically large structures, MLFMM is orders of magnitude more efficient than MoM. It makes no physical approximations and is just as accurate as MoM. For example, using MLFMM, a satellite with an integrated, 106-element patch antenna array can be solved using 6.6 Gigabyte of memory on a notebook computer—a massive computational cost savings compared to MoM, which would require 896 Gigabytes.

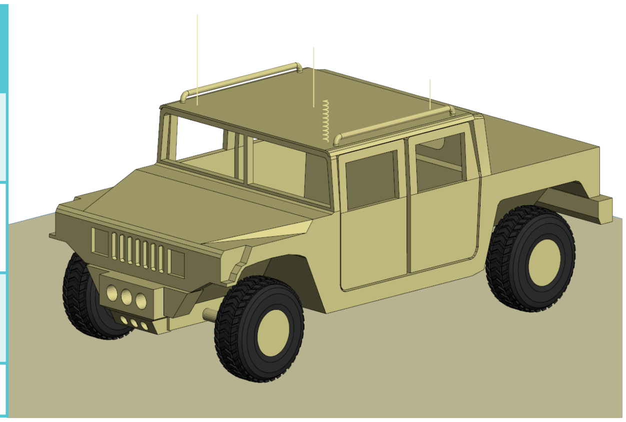


Efficient and Accurate Simulations for Large Structures

Altair is continuously improving the convergence, memory and run time efficiency of Feko's MLFMM. The following comparison of a simulation of a Hummer at 2 GHz with recent releases of Feko illustrates this continuous improvement.

As shown in this example using 20 parallel processes, more recent versions of Feko show significant reductions in both memory usage and simulation run time compared to previous versions.

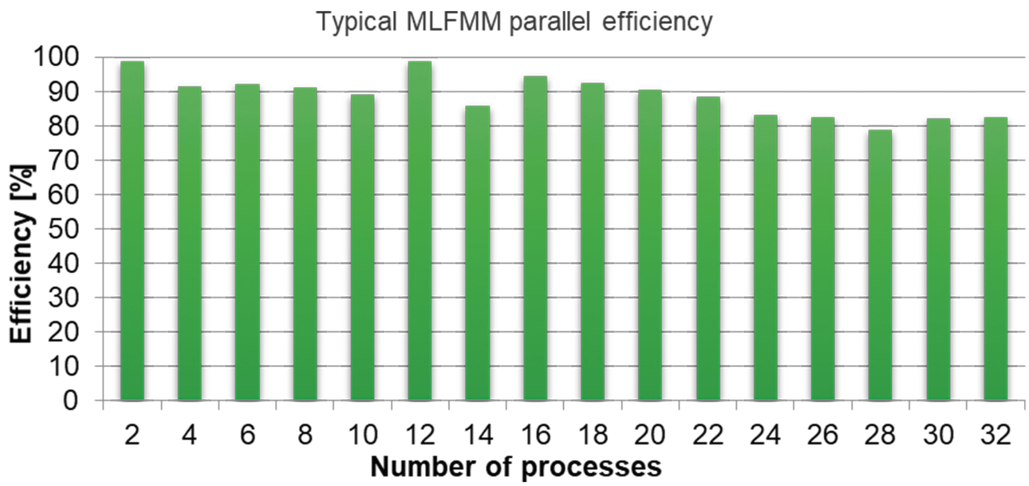
Feko Version	Memory [GBytes]	RunTime [Hours]
2019	188.7	1.73
2020	48.8	0.72
2021*	43.2	0.83
Intel® Xeon® E7-4820 v3 CPUs 20 Parallel Processes		



HIGH-PERFORMANCE COMPUTING

In addition to its fast and efficient methods, FEKO offers various high-performance computing features.

The FEKO solver is fully parallelized and has been optimized to make full use of multi-core CPUs. FEKO is also optimized to fully exploit multi-CPU shared memory resources and is often used on large-scale clusters.

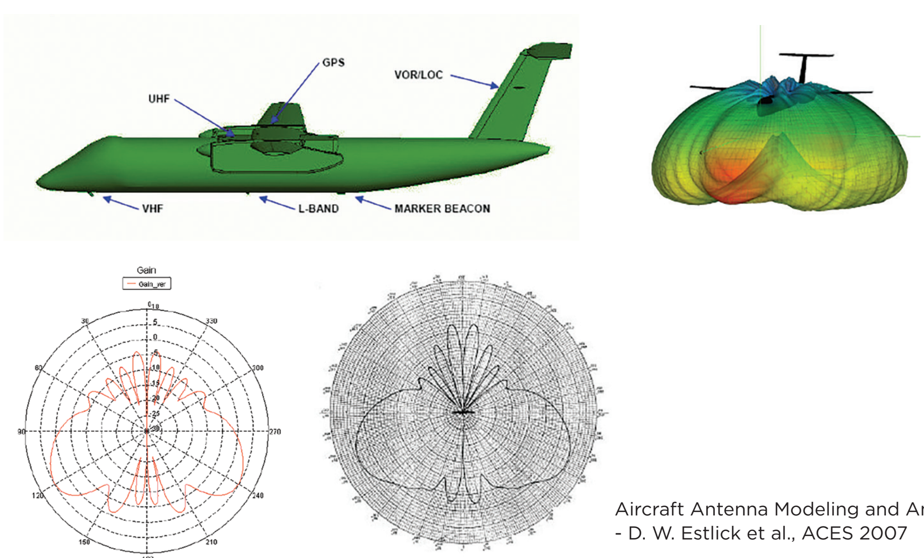


SOLUTION ACCURACY

While simulation results must be produced efficiently, accuracy should always be the top priority. The following examples compare results of Feko simulations with physical measurements of actual antenna performance.

L-Band Antenna on Dash 8 Q300 with PO

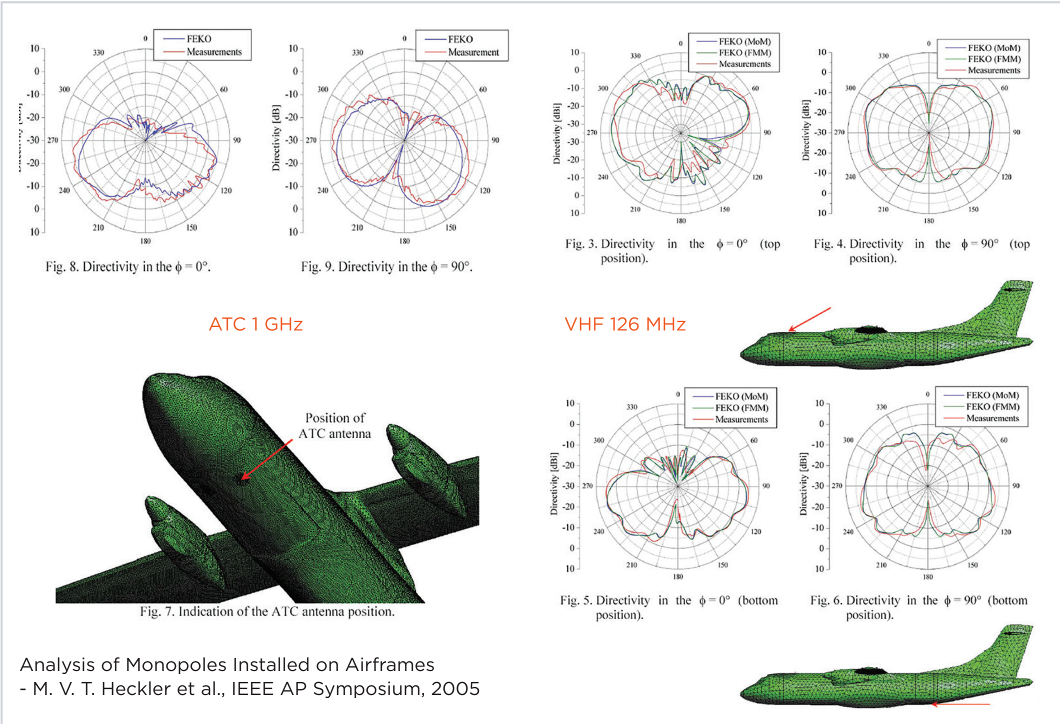
This first comparison is for an L-band blade antenna mounted on the underside of a De Havilland Canada Dash 8 Q300. Comparing the Feko simulation results on the left with the measured antenna performance at right, below, one can see that the simulation is highly representative of the real-world performance.



Aircraft Antenna Modeling and Analysis
- D. W. Estlick et al., ACES 2007

VHF Com and Air Traffic Control

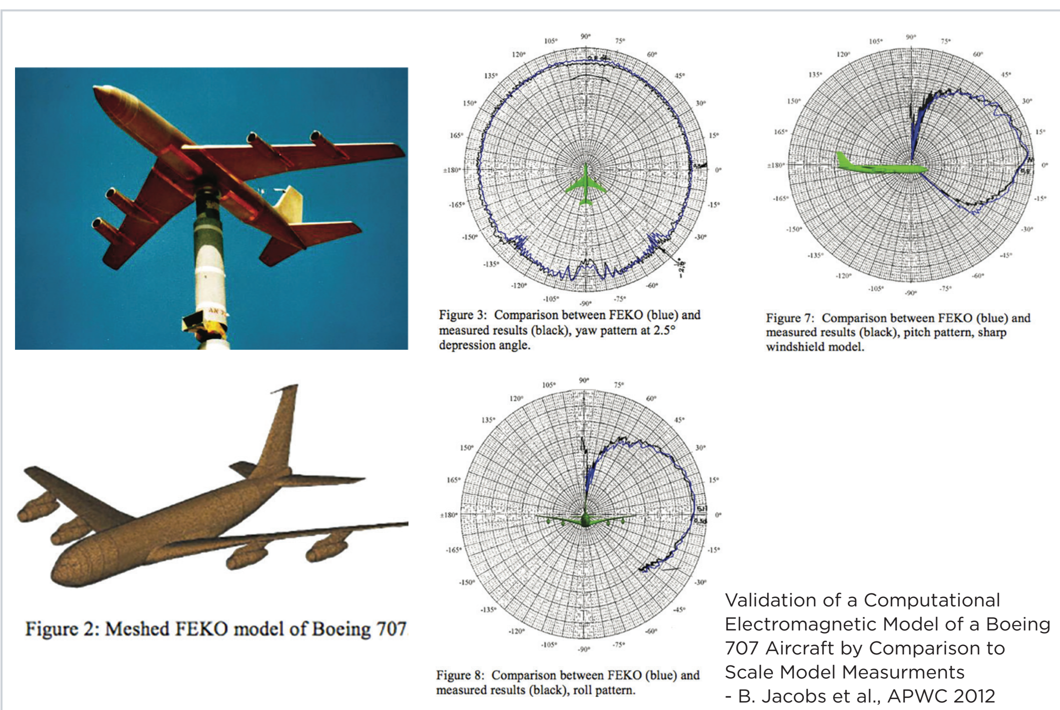
Here, we see comparisons between the Feko simulation and actual measurements for a 1 GHz ATC antenna (left) and two placements of a 126 MHz VHF comms antenna (right) on a large aircraft.



In this example, the Feko results (blue or green) are superimposed over the measured results (red). Again, one can see that the Feko simulations are extremely accurate.

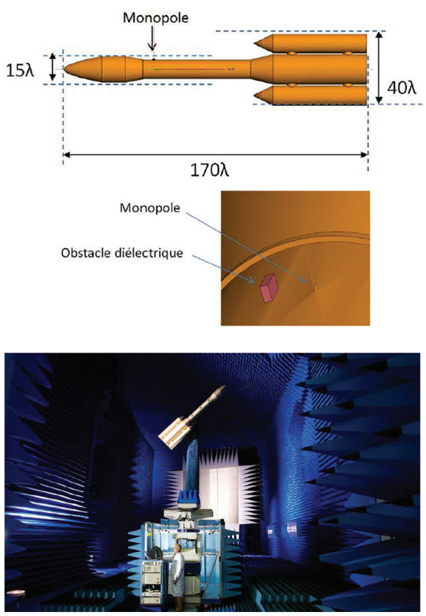
Installed Blade antenna performance at 496 MHz

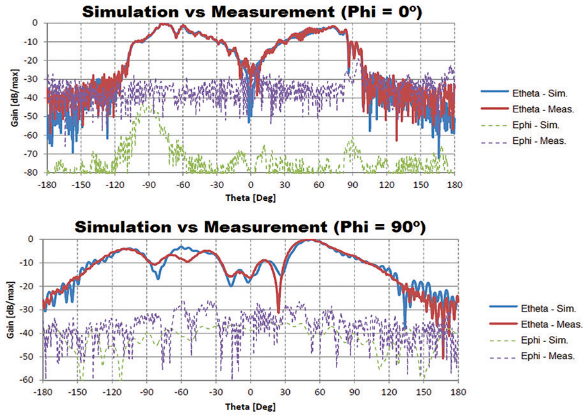
Next, for a 496 MHz blade antenna installed on a Boeing 707, Feko simulation results are compared to measurements performed on a scaled aircraft model. The plots of the simulated performance (in blue) closely track the measured results (in black).



Space Launch Vehicle Monopole Antenna

Finally, for a 17 GHz monopole antenna installed on an electrically extremely large launch vehicle, the simulated results are again compared with measurements made on a scale model. As before, the simulated performance is highly representative of the actual performance.





Methodologie D'analyses Des Diagrammes D'antennes Sur Lanceurs Au Cnes
- M. Romier et al.; CNES March 2016

ANTENNA WORKING ENVIRONMENT

Using the efficient and accurate solvers in Feko, antennas can be designed and analyzed including the effects of their installation on large platforms and the effects of their operating environment.

COMBINED SOLUTION WITH ALTAIR FEKO AND WINPROP

For the analysis of wireless coverage and connectivity in multiple indoor, urban and rural scenarios—also considering all wireless technologies—Altair WinProp technology performs propagation modelling using antenna radiation pattern data from Feko.

WinProp as an integral part of Feko, is the most complete solution in the domain of wireless propagation and radio network planning. With applications ranging from satellite to terrestrial, from rural to urban to indoor radio links, WinProp's innovative wave propagation models combine high accuracy with short computation time.

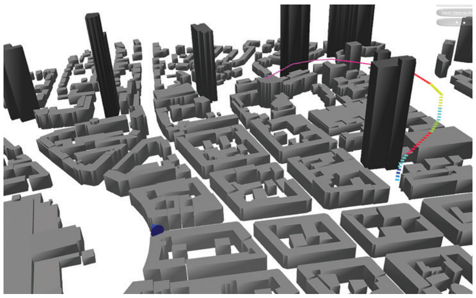
Using different map data (topography pixel data and 2.5 and 3D vector data). Fast and accurate propagation models (including empirical, semi-empirical, and deterministic methods).

WIRELESS CONNECTIVITY WITH NEW VIRTUAL FLIGHT TESTS

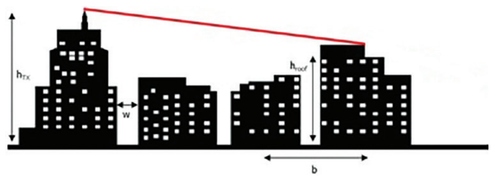
Case of a Drone, Helicopter or Other Aircraft in an Urban Scenario

Feko's new virtual flight test feature can be used to assess connectivity performance withing the aircraft's operational environment.

In this example, a drone flies along a defined path within an urban environment and lands on a rooftop. Connectivity information is produced along the flight path, taking into account both the antenna performance and the topography of the simulated urban environment. Different colors indicate the relative level of connectivity along the flight path.



The drone is flying above the city and landing on a rooftop. In such scenario, the base station antenna provides coverage to the drone and 3D building data is included (in some cases topography is also included).

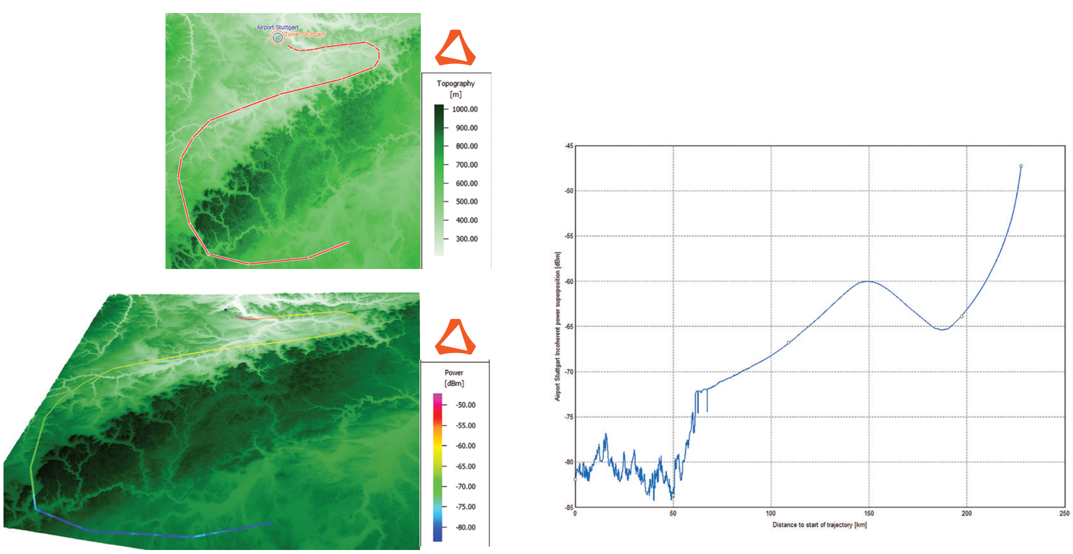


The receiver is located at a height which can be 100m. Such a height requires to consider three different propagation zones or height ranges: (a) high zone, where there is line-of-sight but communication happens through the antenna side lobes, (b) medium zone, above objects, often in line-of-sight, and (c) low zone, where typically there is non-line-of-sight and where the propagation is ground-based.

AIRCRAFT MANUFACTURER CASE

Aircraft Losing Communication with Ground Station During Real Flight Tests

This next case comes from a customer having problems to have a reliable communication between the ground station and the aircraft when flying, being such problem coming from the antennas. Real flight tests are time consuming and costly. To more easily and quickly analyze the problem they wanted to simulate the flight, including the effect of the antennas. To do that, an antenna radiation pattern obtained from Feko is imported into WinProp to take into account the antenna effect in a virtual flight test used to evaluate signal levels along a flight path over a rural landscape.

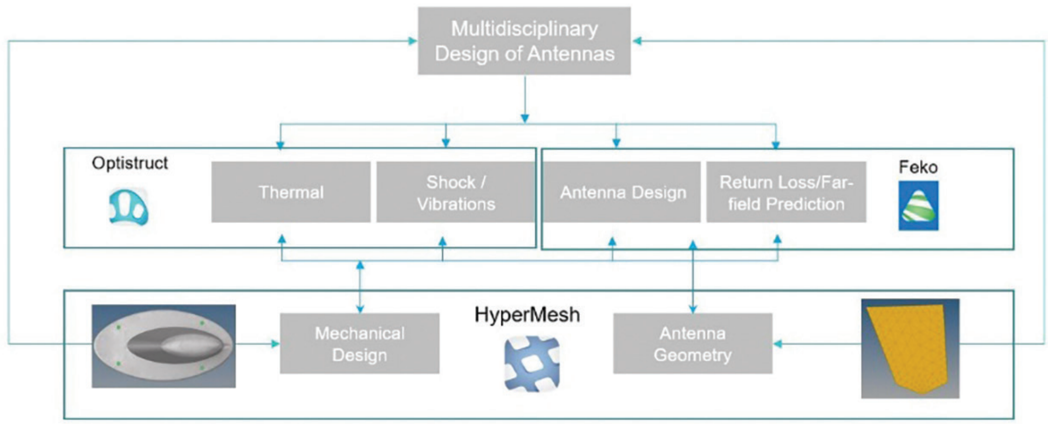


Simulation of real flight test considering: effect of antenna pattern (importing the simulated 3D antenna pattern with Feko of the installed antenna on the aircraft), aircraft orientation (yaw / pitch / roll) which rotates antenna , rural scenario, and evaluation of signal levels along trajectory over distance and time

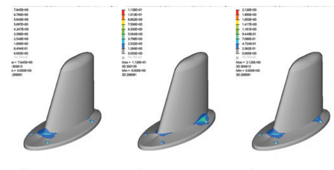
ANTENNA DESIGN FOR ENVIRONMENTAL SPECIFICATIONS — MULTIPHYSICS SOLUTIONS

Antennas are not designed solely to meet electro-magnetic performance specifications. A variety of environmental considerations must also be addressed. For this reason, a multidisciplinary approach to antenna design is required.

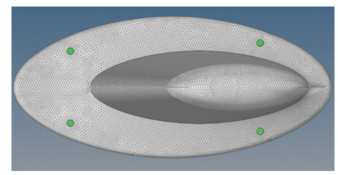
While Feko is used for the antenna design and analysis, Altair's Optistruct can be used for thermal, shock and vibration analysis, using the antenna geometry obtained from the Feko design.



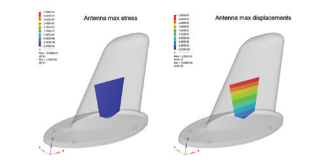
Typical blade antenna on aircraft fuselage



Vibration loading stress plots - 4-bolt configuration



Model of antenna with radome



Maximum stress and relative displacement

Vibration, Shock and Maximum Stress Loadings on a Blade Antenna

Thus, as in the example below of a blade antenna and its radome to be installed on an aircraft fuselage, solutions can be obtained for:

- Vibration stress loading
- Shock loading stress
- Maximum stress and relative displacements
- Thermal loading (not shown)

CONCLUSIONS

As part of Altair's comprehensive Electronic System Design offerings, Altair Feko is able to greatly simplify the design of antennas and the analysis of their installed performance on large platforms. Using Feko in concert with Altair's multiphysics solutions, the performance of antennas can be optimized considering a wide range of platforms and environmental factors.

To see how quickly and easily it the tasks described in this document (among others) can be accomplished using Feko, be sure to view the video version of Optimizing Antenna Installed Performance, part of our Electronic System Design for Aerospace and Defense Webinar Series.