TECHNICAL DOCUMENT

COMPLEX RADOME ELECTROMAGNETICS SIMULATION IN MINUTES

A radar dome, commonly referred to as a radome, is a structural enclosure that protects antennas and electronics from harsh weather and environmental factors without degrading electromagnetic signals to the radar. It is designed to withstand structural and wind loading while having minimal impact on the electrical performance of the antenna. The design of radomes, especially those containing multiple layers and curved frequency selective surface (FSS) elements, are extremely complex, with the modeling and simulation of these systems commonly taking days and even weeks to complete.

Overview

Radomes are used across multiple industries, including aerospace, defense, electronics, and telecommunications. When properly designed, the radome can actually enhance the performance of an antenna system. The proper selection of a radome for a given antenna can help improve the overall electromagnetic system performance by eliminating wind loading, allowing for all-weather operation, and providing shelter for installation and maintenance. Altair's radome simulation solution helps to streamline the design of these complex components, ensuring performance while significantly reducing development time.

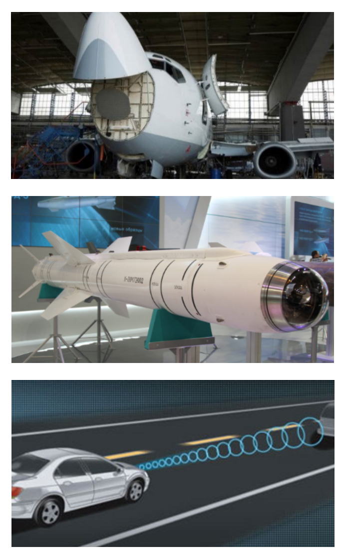
Design Complexity Challenges

Radomes can impact the electromagnetic (EM) behavior of antennas as well as radar cross-section (RCS) performance. Some factors to consider include:

- Dissipative losses within a dielectric material
- Electric phase shifts introduced by presence of the radome
- Internal reflections

In order to accurately model a radome and it's influence on EM performance, designers typically focus on performance parameters like radome insertion loss, increased antenna sidelobe levels, boresight error, and effects on RCS.

Radome development is typically a lengthy process, often requiring costly iterative prototyping, testing, and production cycles. Simulation can significantly reduce this development time, but due to the electrical size of these simulations, legacy simulation methods can fall short if they cannot produce insights in time to inform the design process.

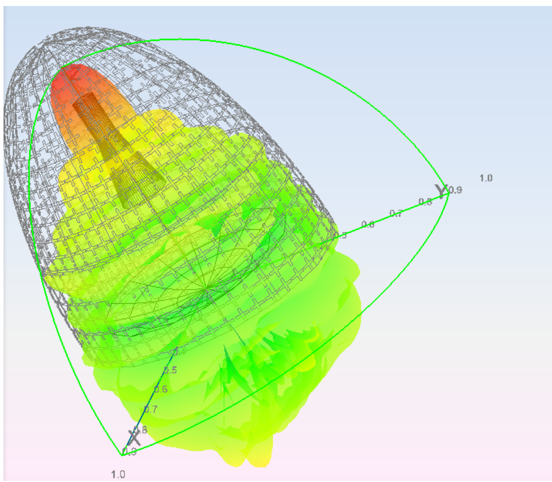


Examples of radomes in the aerospace, defense, and automotive industry

Simulation-driven EM Design Solutions for Radomes

Altair Feko™ is the fastest solution to analyze radomes, including for electrically large problems and frequency selective surfaces. These thin, repetitive surfaces are designed to reflect, transmit, or absorb electromagnetic fields based on the frequency of the field. FSS allow designers to tailor the frequency behavior of the radiating system, the antenna and radome, while reducing the RCS of the radome. Feko also enables the automated design of reflectarray and ultra-conformed reflector antennas, analysis of doppler effects, and ultrasound systems often used in automotive applications.

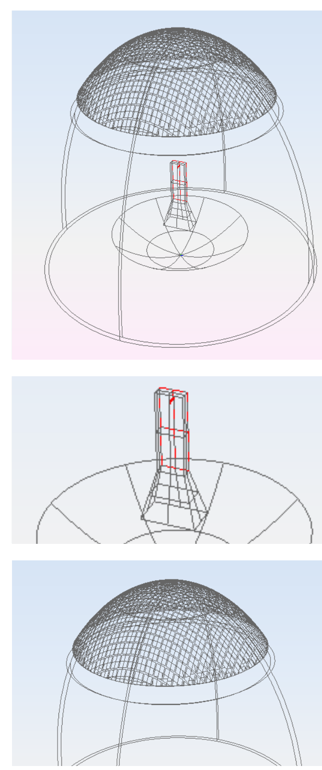
Simulation with Feko helps speed up the analysis of complex radomes and identification of RCS problems in a few ways. First, modelling is made easier with automatic FSS mapping to each radome layer, making a process that can take hours or days achievable in less than an hour. Additionally, optimization of the radome can be identified based on MoM/MLFMM (Method of Moments/Multilevel Fast Multipole Method) with MPI/OpenMP parallelization.



EM simulation of a radome including FSS

Full Wave Analysis

The full wave analysis solver available in Feko provides analysis with MoM/MLFMM using curved (conformed) basis functions to minimize discretization errors. Using a tailored CBFM iterative approach for radome problems, the antenna and radome are analyzed separately, reducing computational cost, improving convergence, and reducing the effective size of the problem and total number of unknowns in the simulation. This approach offers the same accuracy as conventional approaches with greater efficiency and speed.



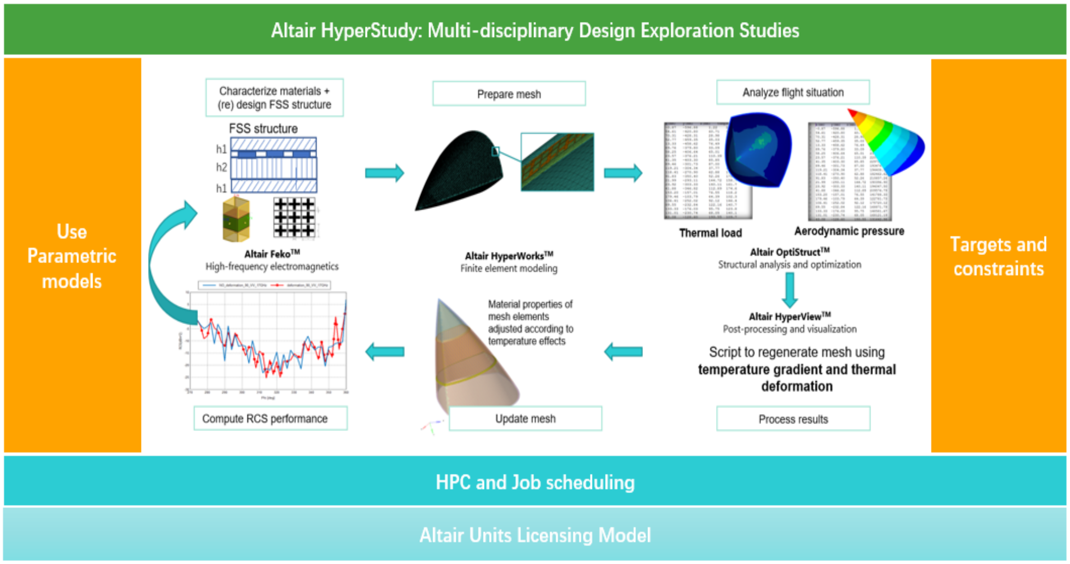
Full wave analysis uses an iterative approach, analyzing antenna and radome separately for increased efficiency

Mitigating Radome Thermal Deformation Effects on RCS

When coupled with Altair's structural simulation and optimization solvers, highly flexible workflows can be constructed that account for the impact of non-electromagnetic properties and even situational effects on RCS.

For the design of a complex radome such as one intended for supersonic flight, the radome shape profile may vary, the nosecone structure will involve multiple layers, and it will require FSS to be designed. Feko can work with advanced shapes, analyze complex layered structures, and has special design and analysis tools for FSS.

The friction at these high speed will create heat and mechanical deformation on the radome, factors effecting RCS that Feko alone cannot account for. But by coupling Feko EM simulation with Altair OptiStruct™, designers can analyze the flight situation, its effects on the structure, and subsequent changes to RCS performance. These results then inform potential redesign efforts needed in the FSS structure. Using parametric models in Altair HyperStudy™, an optimization of this workflow can be undertaken to quickly determine the optimal balance of EM and structural attributes on this complex radome design.

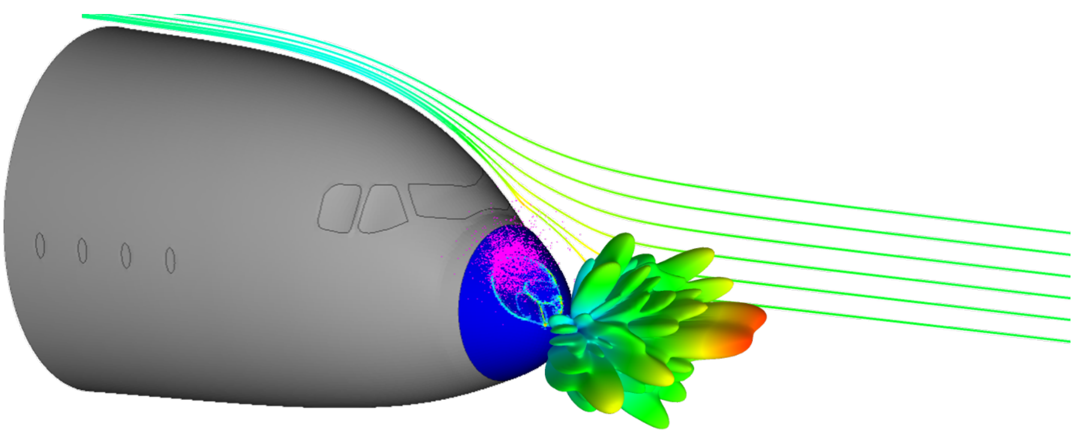


[Want to learn more? Watch the webinar.](#)

Considering Multiphysics in Radome Development

Radomes are a multiphysics problem. Designers must ensure that these complex, multi-function components adequately protect critical antennas and electronics, that the radome structure is aerodynamically efficient, and that it delivers the desired electromagnetic transparency. Together, virtual physics-based models help to characterize a radome's performance and can be used to drive informed design decisions while saving engineering time and costs.

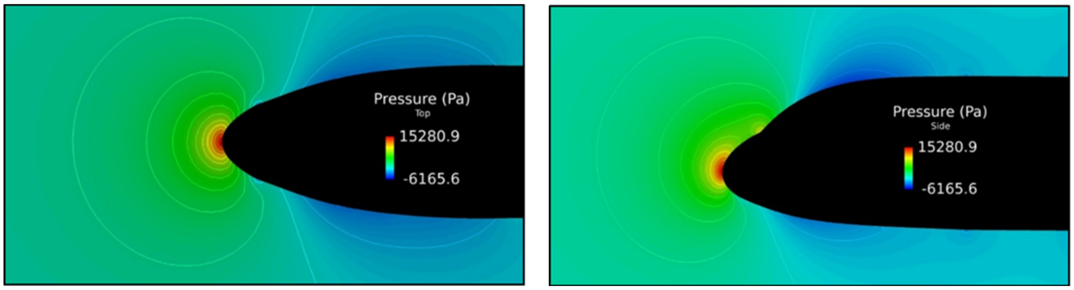
In this example, we examine the multiphysics simulation of an aircraft nosecone radome.



Aircraft radome simulating EM, CFD, and bird strike

Aerodynamics

The nosecone is a critical component of the overall aerodynamic performance of an aircraft. Altair CFD™ is a computational fluid dynamics (CFD) solver which designers can use to predict the air pressure field that surrounds an aircraft during flight. The resulting pressures can then be mapped onto a structural analysis model to accurately predict the structural response of the radome under aerodynamic load.

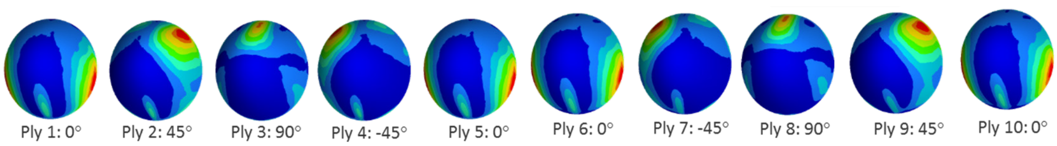


Aerodynamic analysis of an aircraft radome

Structural analysis

It is possible to map CFD pressures onto the radome model for structural analysis study. Large displacement nonlinear static stresses from high winds are calculated with Altair OptiStruct™ to determine if buckling will occur. Optistruct even allows engineers to examine stresses on individual fiberglass ply levels to determine the influence of fiber direction on structural performance.

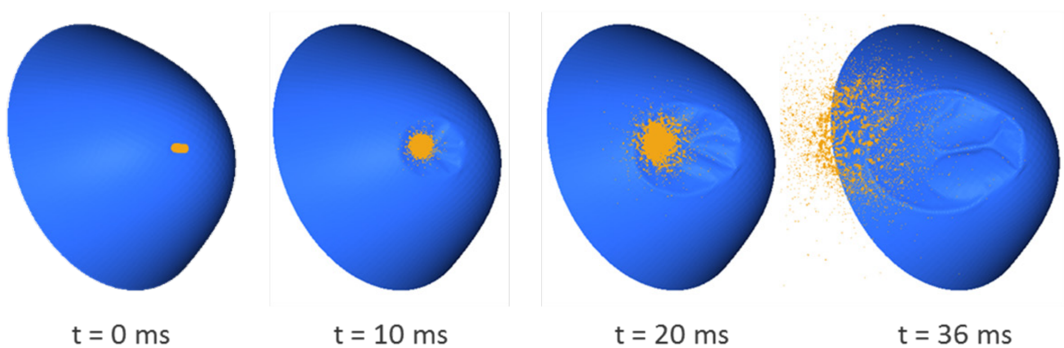
The OptiStruct structural solver interacts with Altair CFD solvers for practical fluid-structure interaction (FSI), thermal FSI, and direct coupling FSI, which offer uni-directional or bi-directional coupling. Similarly, OptiStruct couples uni-directionally with electromagnetic solvers including Altair Feko™.



Large displacement nonlinear static analysis of individual radome ply layers

Impact

With more than 17,000 incidents in the U.S. in 2019, bird strike remains a significant threat to the airworthiness of aircraft radome structures and the instrumentation they protect. Altair Radioss™ has validated bird models and multidomain simulation to reliably identify and help reduce bird strike damage. Radioss can be used to predict performance of the radome under dynamic loadings, such as the damage likely to be incurred from high-speed bird strike, hail, or other impact scenarios.



Bird strike simulation on an aircraft radome

Multi-disciplinary Design Optimization

The Altair HyperStudy™ design exploration tool can be used to perform trade-off studies and optimize the design for performance and reliability. In this particular radome optimization, the design objective was to minimize mass, with the constraints that the radome shape could not significantly change so as to preserve aerodynamic properties, it could not incur shape change due to aerodynamic buckling or deflection, it could not deviate outside a suitable transmission coefficient range, and that it must meet bird strike fracture performance criteria.

Ply thickness was used as the design variable, with HyperStudy used to optimize the thickness of each fiberglass ply layer as well as the inner foam core factoring in EM, CFD, and structural performance criteria. The optimization run found that with fewer composite plies and a slightly thicker foam core, the multi-disciplinary performance criteria could be met while reducing mass by 31 percent.

Working with Altair

Altair software is used to solve a broad range of electromagnetic problems from static to low and high frequencies. Whether your application requires multiple frequency and time-domain techniques with true hybridization to enable efficient exploration of a broad spectrum of electromagnetic performance, or the simulation of magneto static, steady-state and transient conditions, we have the tools you need.

Altair Feko is used globally across multiple industries including aerospace, defense, automotive, communications, and consumer electronics to reduce the time-to-market. Feko addresses the broadest set of high-frequency electromagnetics applications, allowing teams to optimize wireless connectivity, including 5G, ensure electromagnetic compatibility (EMC), and perform radar cross section (RCS) and scattering analysis.

To learn more, visit altair.com/feko-applications