Antennas are mounted on the exterior of today's airliners.

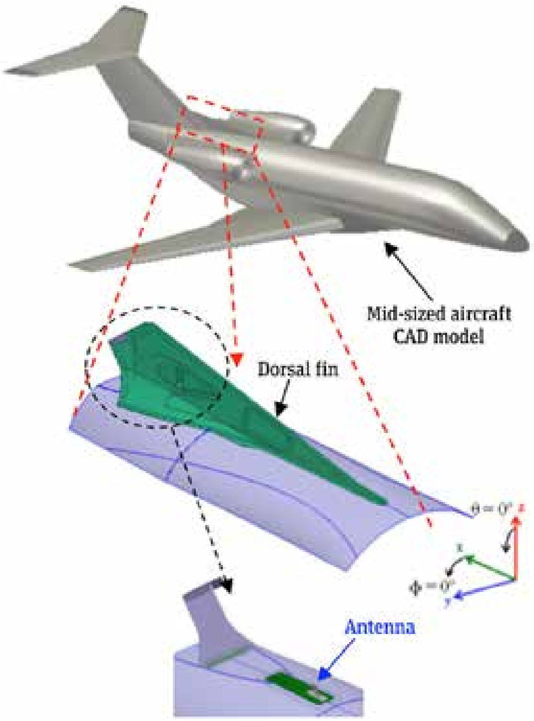
Inside Story

The scores of antennas extending from the surface of today's jet airliners create drag that adds to fuel consumption. Brazilian National Institute of Telecommunications (Inatel) and Embraer engineers have been developing new ways of installing antennas that could save fuel. With ANSYS simulations, engineers can predict the performance of proposed installations without the time and expense of building prototypes.

By **Arismar Cerqueira Sodré Junior**, Associate Professor,
Brazilian National Institute of Telecommunications (Inatel),
Santa Rita do Sapucaí, Brazil; and
Sidney Osses Nunes, Product Development Engineer, Embraer,
São José dos Campos, Brazil

"Placing antennas in their traditional position on the exterior of the *aircraft increases drag*, which intensifies fuel burn at a time when airlines have mandates to be *increasingly energy efficient*."

The number of antennas on commercial aircraft is steadily rising to support new safety, navigational and radar systems and to deliver services, such as Wi-Fi and live TV, to passengers. However, placing these antennas in their traditional position on the exterior of the aircraft increases drag, which increases fuel burn at a time when airlines need to be increasingly energy efficient. To address this challenge, Embraer is working on new installation designs for aircraft antennas. Antennas must still emit the same amount of radiation in every direction, so many design variations must be evaluated. If physical prototypes had to be built and tested for every proposed antenna and position, it would be extremely costly and time-consuming. The Brazilian National Institute of Telecommunications (Inatel) and Embraer are using ANSYS HFSS electromagnetic field simulation software to evaluate the performance of alternative antenna installation designs. HFSS simulation results match closely with physical testing, and therefore greatly reduce the amount of time required to assess design alternatives. The result may be substantial fuel savings in future Embraer aircraft.



A light jet aircraft and the ANSYS HFSS numerical model of its dorsal fin

Using Actual Antenna Installation for Validation

The latest generation of commercial airliners have up to 100 antennas that are used for air traffic control (ATC), traffic collision avoidance (TCA), instrument landing systems (ILS), distance measuring equipment (DME) and many other applications. In the past, aircraft exterior structures were primarily made of aluminum, which largely blocks electromagnetic radiation, so antennas had to protrude from their surface. Now many aircraft are built from fiber-reinforced composites, giving rise to new electromagnetic challenges for antenna placement and making it more difficult to design antennas into the aircraft fuselage. Besides reducing drag, this approach also can potentially reduce weight by eliminating the protruding structures now required to support antennas.

To simulate proposed antenna installation designs, Inatel and Embraer engineers first needed to determine the electromagnetic properties of the composite in which the antenna would be covered.

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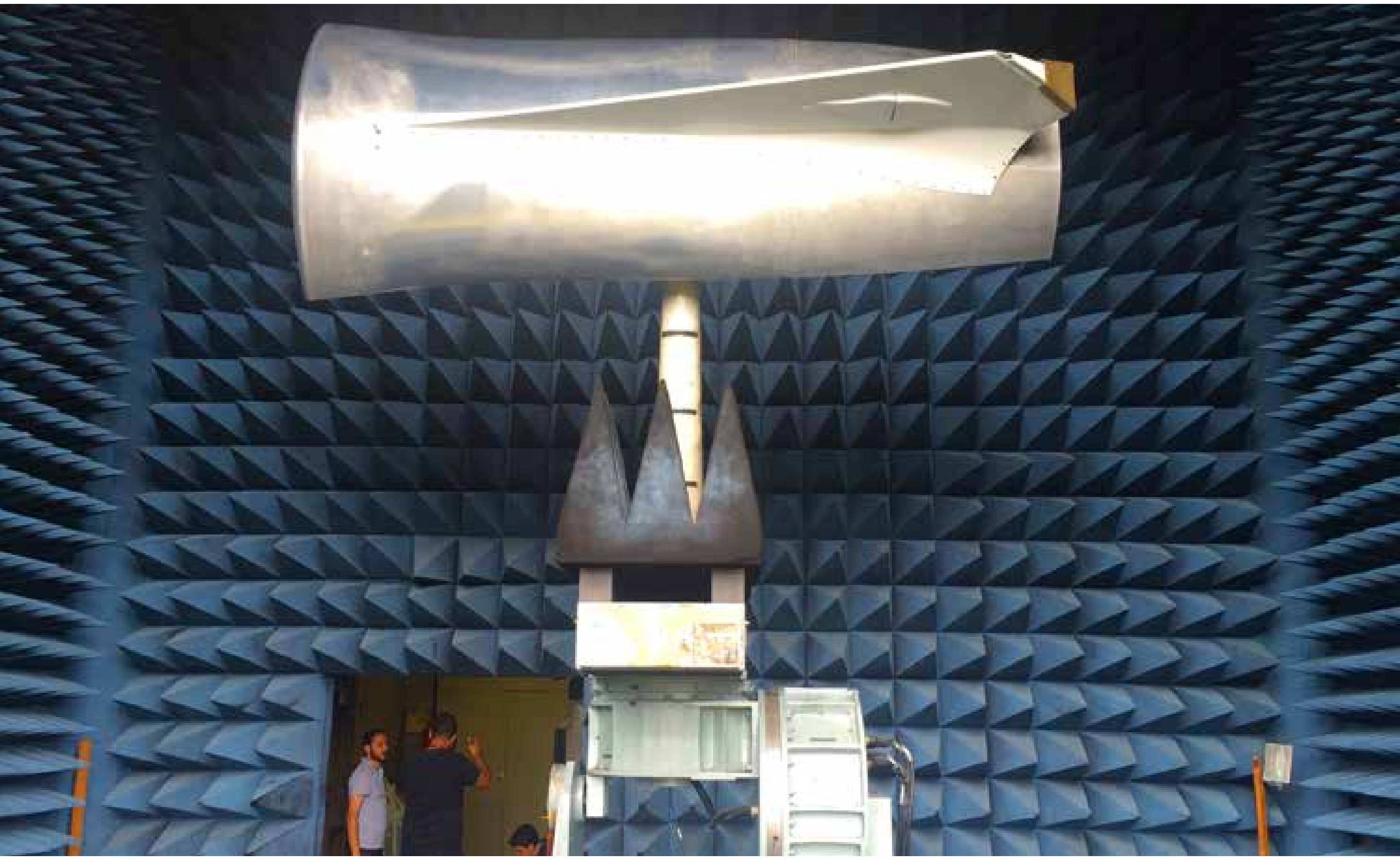

Prototype of aircraft dorsal fin tested in anechoic chamber

They built a physical prototype of a composite dorsal fin sheltering an existing antenna. They excited the antenna and measured the resulting radiation pattern in an anechoic chamber, which enables accurate measurement of antenna radiation by eliminating reflections of electromagnetic waves as well as waves entering from outside.

Engineers measured electrical permittivity, loss tangent and the radiation pattern of the antenna so that they could use these measurements to define the composite material properties in HFSS. They imported the geometry of the structure and antenna from computer-aided design (CAD) models. The HFSS meshing algorithm generated and adaptively refined the mesh, iteratively adding mesh elements where needed due to localized electromagnetic field behavior. The next step was to define boundary conditions to specify field behavior on the surfaces of the solution domain and on the object interfaces. Ports were defined where energy enters and exits the model. A sine wave signal was used to excite the antenna.

ANSYS HFSS Perfectly Matched Layer Boundary Automation
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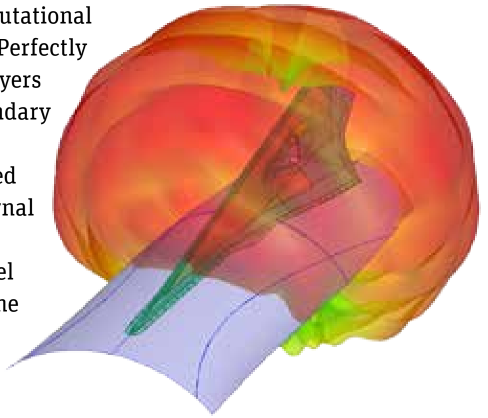
Hybrid Solver Technology Saves Time

Inatel and Embraer engineers used the ANSYS HFSS hybrid method, combining a finite element model of the dorsal fin with an integral equation model of the fuselage and antenna. The finite element method was selected for the dorsal fin because the dielectric properties of this structure were critical and the finite element method allows them to be precisely defined. The integration equation or method of moments (MoM) technique within HFSS was used for the rest of the aircraft and antenna because of its computational efficiency. Perfectly matched layers (PML) boundary conditions were applied to the external boundaries of the model to reduce the amount of



ANSYS HFSS simulation results show radiation amplitude field generated by antenna designed within fuselage.

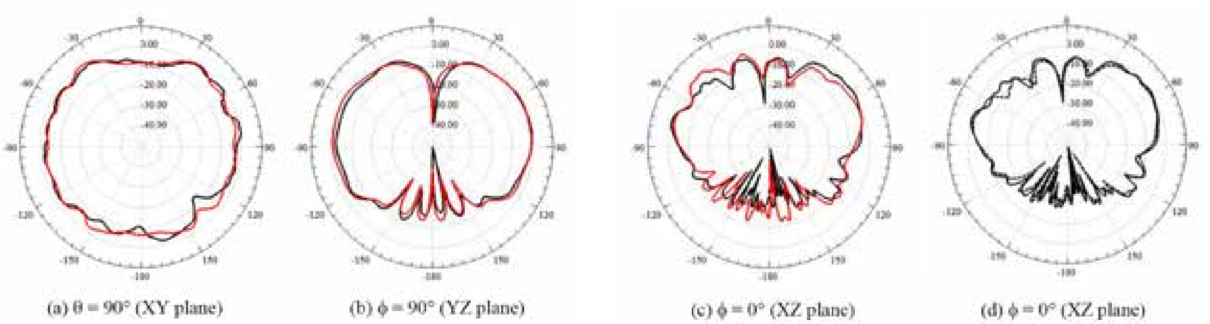
“Engineers discovered that the *position of the antenna* with respect to the composite and the thickness of the *composite structure* had the greatest impact on antenna performance.”

air in the computational domain. PMLs are fictitious complex anisotropic materials that fully absorb the electromagnetic fields impinging upon them. They were placed at the model boundaries to emulate reflection-free radiation.

ANSYS HFSS computed the full electromagnetic field pattern inside the structure and calculated all modes and all ports simultaneously for the 3-D field solution. The simulation results correlated well with physical testing, validating both the measured material properties and the HFSS simulation model. Engineers determined that the performance of different fiber-reinforced composites are dependent on frequency. For example, at 100 KHz a significant amount of carbon fiber reinforcement can be used without harming the radiation pattern, but at 10 GHz even a very small amount of carbon fiber presents major design challenges.

Iterating to an Optimized Design

Engineers then evaluated different antenna installation designs with the goal of obtaining an omnidirectional radiation pattern. By changing the dimensions of different design parameters, they discovered that the position of the antenna with respect to the composite structure (in the x and y directions) and the thickness of the composite structure had the greatest impact on antenna performance. Engineers used the parametric design capability in HFSS to evaluate ranges of values for these and other design parameters in batch mode. Next, engineers modeled the complete aircraft structure to determine how it affected the performance of the antenna and made further changes to the design to maintain omnidirectional performance.



Comparison of simulated (red and dashed line) and measured (black) radiation patterns show close agreement.

Guided by simulation, engineers developed an antenna installation that provides a radiation pattern very close to the desired omnidirectional pattern, nearly matching that of the uncovered antenna. After optimizing the design of the antenna, Inatel and Embraer engineers built a prototype of the optimized design. Physical measurements of the new prototype closely matched the simulation. These new installation designs for antennas have the potential to substantially reduce fuel consumption in next-generation aircraft.

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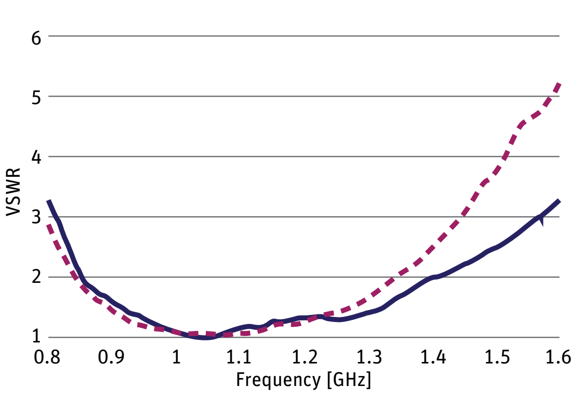

Measurements of final antenna design show that it closely matches performance of conventional antenna at frequencies of interest between 1 and 1.2 GHz.

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