

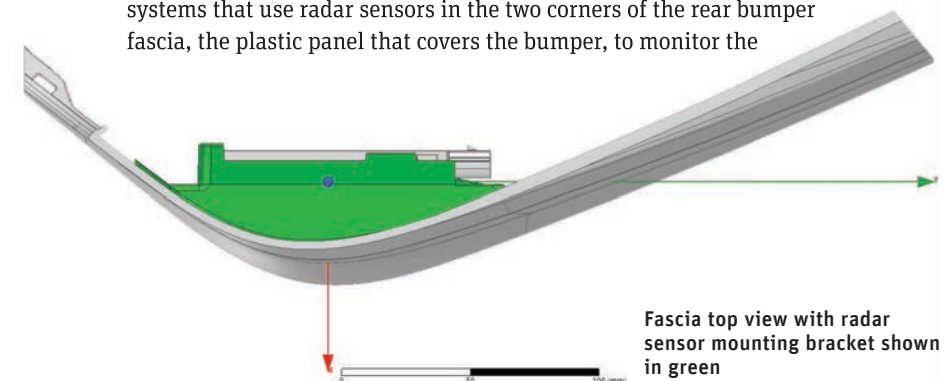
# On the Radar

Radar systems play a critical role in today's driver assistance systems and upcoming autonomous vehicles. These systems must be accurate to provide the needed functionality and safety. Autoliv uses ANSYS electromagnetic field simulation software to evaluate alternative radar integration scenarios early in the automotive development process to pioneer reliable systems and avoid costly design revisions.

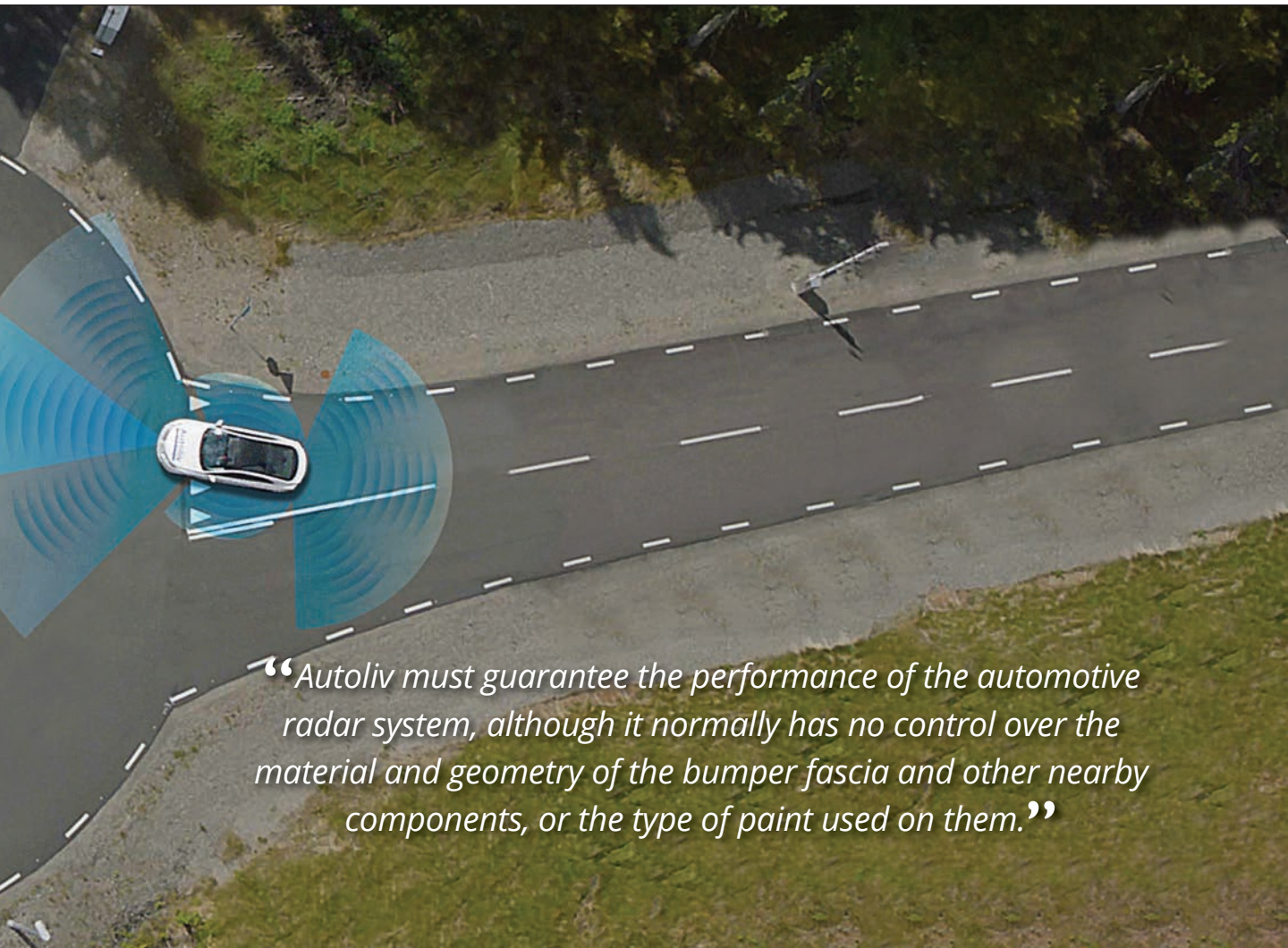
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Vehicle safety and autonomous driving require ever-increasing numbers of radar systems looking outward at the vehicle's environment. The packaging design of these radar systems is carried out early in the vehicle development process, before a prototype vehicle is available for performance testing. If engineers get the design wrong, the packaging process may have to be repeated at a cost of about \$1 million and possible delays to the vehicle launch. Autoliv, the worldwide leader in automotive safety systems, avoids these costs by using ANSYS HFSS to predict how the fascia and other nearby components affect radiation patterns so they can validate the design long before the prototype phase.

For example, many of today's vehicles are equipped with blind spot detection systems that use radar sensors in the two corners of the rear bumper fascia, the plastic panel that covers the bumper, to monitor the

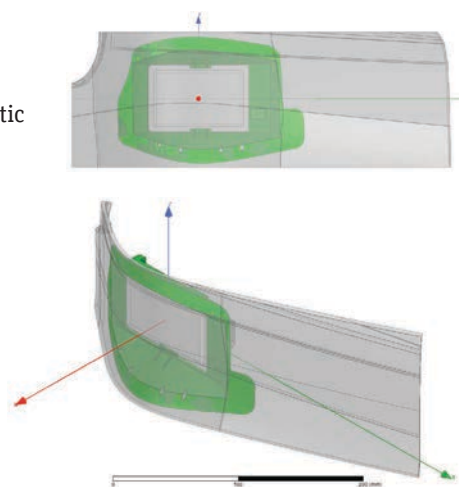


Fascia top view with radar sensor mounting bracket shown in green



presence, direction and speed of vehicles in adjacent lanes. If a vehicle is present in either of the driver’s blind spots, a warning indicator on the side view mirror lights up. Many current vehicles also have a radar sensor in the middle of the front bumper to enable features such as forward collision warning, which detects vehicles or objects that the driver might hit if not noticed. Fully autonomous vehicles are expected to have these and more radar systems mounted behind the bumper fascia and other body panels.

Radar systems use a transmitter to emit a short pulse of electromagnetic radiation. After each pulse, the transmitter is turned off and a receiver listens for signals caused by the pulse reflecting off nearby objects. Electromagnetic radiation emitted by a radar sensor may be distorted in difficult-to-predict ways by objects that the radiation must pass through. Other nearby objects may generate reflections that interfere with the receiver. When integrating a radar sensor in a new vehicle, engineers must position the system so that the fascia and mounting bracket do not interfere with its accuracy. This means obtaining a high and relatively constant signal across the azimuth (from side to side) of the sensor while minimizing wasted energy delivered to undesired directions or reflected by the bumper fascia back to the radar. The geometry of the bumper fascia is often complex because it has to meet multiple goals that include durability, safety, aesthetics and manufacturability. A slight change in sensor position can be the difference between meeting or not meeting accuracy requirements. Autoliv must guarantee the performance of the



Truncated section of CAD file of bumper fascia used for simulation, with radar sensor position

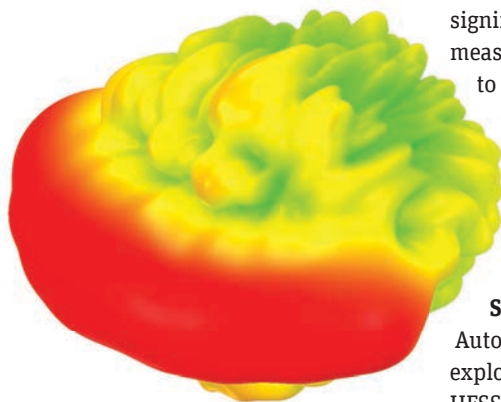


*“If, during drive testing, Autoliv engineers discover that the position of the radar or bracket geometry makes it impossible to meet the performance requirements, the entire process must be repeated at a cost approaching \$1 million.”*

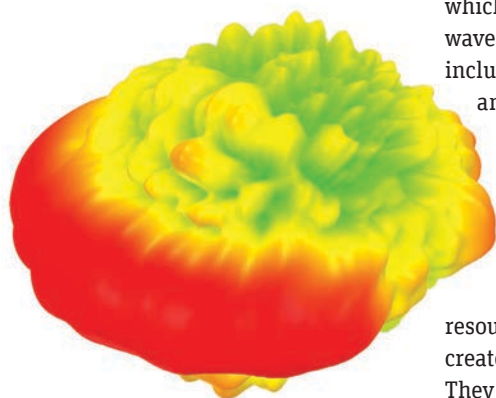
automotive radar system, although it normally has no control over the material and geometry of the bumper fascia and other nearby components, or the type of paint used on them.

### Impact of Packaging Design on Radar Accuracy

To meet the vehicle launch date, Autoliv must first create the packaging design. This mainly consists of determining the best position for the sensor in relation to the fascia and designing the mounting bracket, before the vehicle or even the fascia is available for testing. Autoliv invests significantly in packaging design, instrumenting the vehicle prototypes with measurement equipment and in test driving in many different environments to evaluate the accuracy of the radar. If, during drive testing, Autoliv engineers discover that the position of the radar or bracket geometry makes it impossible to meet the performance requirements, the entire process must be repeated at a cost approaching \$1 million. The additional design iteration also adds eight to 12 weeks in lost program time, which could potentially delay the vehicle launch.



Sensor transmit radiation pattern without fascia



Sensor transmit radiation pattern with fascia

### Simulating Radar Performance in the Vehicle

Autoliv avoids this potential problem by using ANSYS HFSS to digitally explore and evaluate radar sensor packaging designs before prototyping. HFSS has demonstrated predictive power in many different programs and applications. The simulation process begins by obtaining physical samples of the bracket and fascia materials to determine their electrical properties, which are required to run accurate electromagnetic simulations, using either waveguide or quasi-optical techniques. The measured electrical properties include the dielectric constant and loss tangent of the fascia, paint layer and bracket.

Autoliv engineers use a computer-aided design (CAD) file from the automobile’s original equipment manufacturer (OEM) that contains the current geometry of the bracket, fascia and other nearby components. ANSYS SpaceClaim is used to translate and prepare the CAD for HFSS import and meshing improvement. They truncate the fascia in the simulation model to both conserve computational resources and preserve electromagnetic fidelity. Engineers have already created ANSYS HFSS models of all of the company’s current radar systems. They select the radar system to be used on the vehicle and position it within the bracket of the simulation model as an initial design according to Autoliv packaging guidelines. Then engineers assign measured electrical properties of the fascia, paint and bracket to their respective objects within the model. The simulation is run employing ANSYS HFSS, ANSYS HFSS-IE solver and ANSYS High-Performance Computing.





Predicted versus measured radar sensor bearing prediction error


### Meeting Accuracy Requirements

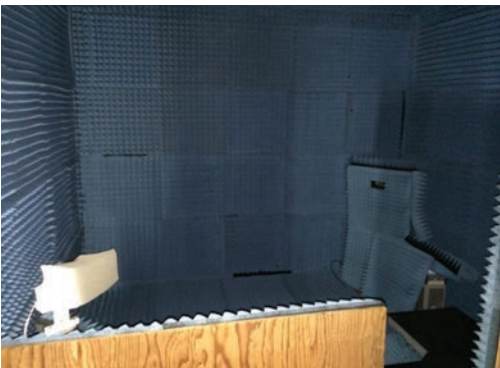
The simulation results are then post-processed in HFSS and exported into a custom MATLAB program that mimics the algorithm used by the radar sensor to evaluate radar performance, including signal-to-noise ratio, field of view, bearing bias and bearing ambiguity. It allows engineers to determine, for example, the maximum distance at which the radar can detect an object with a given radar cross section at a given azimuth angle, such as an oncoming motorcycle in the next lane at a distance of 30 meters.

If predicted performance does not meet minimum requirements,


geometrical countermeasures are necessary, such as relocating the radar, and then the simulation process repeats. The geometry of the fascia is also likely to change during the design process, but when changes occur, Autoliv engineers obtain the new geometry, run their simulations again and, when necessary, modify their design.

Integrating a radar sensor into a vehicle so that it will deliver the high levels of accuracy required to meet government regulation and customer expectations is a

challenging task. Autoliv engineers have used ANSYS HFSS electromagnetic field simulation software to integrate many radar systems into new vehicles without a single issue that required an additional design iteration. Simulation also has helped engineers identify improvements in packaging design that made it possible to substantially increase the range and accuracy of the radar system. 



Anechoic room used for fascia materials testing

  
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