

The Path of Least Resistance



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When lightning strikes an automobile, the metal frame provides the path of least impedance to the ground, protecting the vehicle's occupants from injury. But as lightning flows over the frame or through the vehicle's electrical systems, it can damage sensitive components or even melt solder joints. The amount of electronics in vehicles is on the rise, so

protection from lightning is becoming more important than ever. Fiat Chrysler Automobiles, with support from ESSS, the ANSYS channel partner in South America, uses ANSYS electromagnetic field simulation software to model lightning strikes and predict their impact on vehicle electronics so that future vehicles can be designed to be more resistant to damage.

Vehicles now depend on their electronics systems for safety and reliability, and even to function. A loss of these systems is not only inconvenient but could be dangerous. About 70 percent of lightning strikes occur in the tropical regions of the world because they are more prone to the formation of clouds that produce thunderstorms. Fiat Chrysler Automobiles (FCA) Brazil is particularly interested in protecting vehicles from lightning because Brazil is the largest tropical country in the world and data suggests that lightning strikes Brazil around 80 million times per year. Testing vehicle performance in a lightning strike is expensive because engineers must rent special test facilities and build a prototype which could be destroyed in testing. FCA and ESSS engineers worked together to simulate the effects of a typical lightning strike on a Fiat Mobi city car. This project was not part of standard vehicle development.



Simulating Lightning Strikes
in Maxwell
ansys.com/simulating-lightning

“Engineers used ANSYS Maxwell to calculate the probability of lightning striking different areas of the vehicle.”

LIGHTNING AND AUTOMOBILES

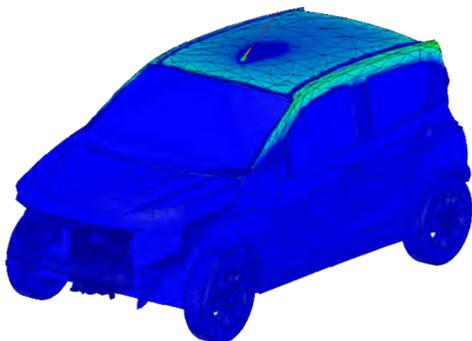
Lightning in the vast majority of cases is an electric discharge between the negatively charged bottoms of clouds and the positively charged surface of the ground. When sufficient negative charges build on a cloud, a flow of negative charge, called a stepped leader, rushes toward the earth. The positive charges on the earth are attracted to the stepped leader, so they flow upward from the ground. When the upward and downward leaders meet, the resulting electric current is seen as a bright flash.

Lightning typically flows through conductive structures that have high charge density, such as sharp tips and corners, as it seeks out the path of least electrical impedance. This explains why lightning rods typically consist of pointed metal rods and why automobile antennas are a common lightning target. Lightning flowing over the vehicle body may induce an electric field that generates voltages and currents in wiring harnesses that travel to electronic control units (ECUs). This could potentially damage one or more of the scores of ECUs that function as the brains of the automobile.

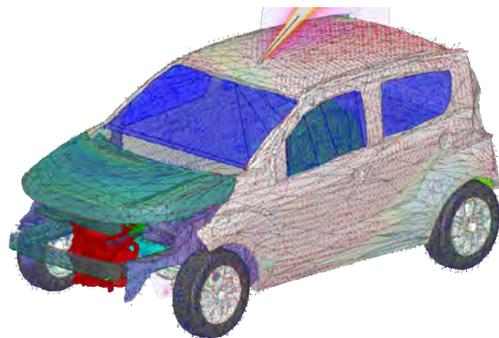
The electric fields generated inside an automobile by a lightning strike are highly dependent on the geometry and conductivity of the vehicle exterior. In the case of a perfect sphere, the electrons forming the charge will spread out uniformly over the outer surface, canceling each other out with the result that no charge will be generated inside the sphere. In a vehicle with more complex geometries and differences in the conductivity of components, such as tires and windshields, significant internal electric fields may be generated; determining these fields is a challenging task.

Physical testing is far from an ideal solution because there are only a few facilities in the world capable of simulating a lightning strike. The cost of using these facilities runs into the millions of dollars and requires the construction — and possible destruction — of a prototype vehicle costing hundreds of thousands of dollars.

 **Lightning Strikes More Than Once**
[ansys.com/lightning-strikes](https://www.ansys.com/lightning-strikes)



Electrostatic simulation shows electrostatic charge on each area of vehicle in an electromagnetic field.



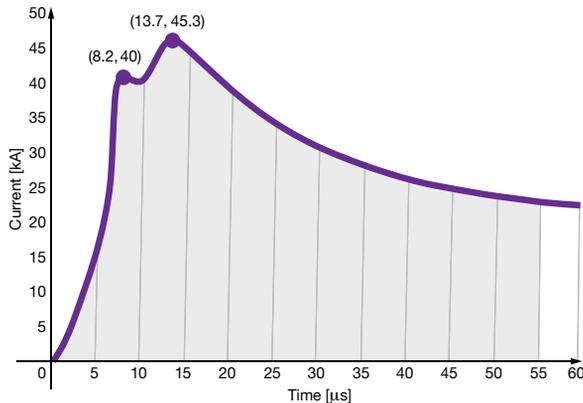
Transient simulation results show currents on the surface of vehicle as a result of a lightning strike.

DETERMINING WHERE LIGHTNING IS LIKELY TO STRIKE

FCA and ESSS engineers first used the ANSYS Maxwell electrostatic solver to calculate the probability of lightning striking different areas of the vehicle. They generated an electric field throughout the solution domain by placing a charge of 100 coulombs on the top surface of the model and 0 coulombs on the bottom surface. When they first solved the model without a vehicle, the charge was evenly distributed throughout the solution domain.

Next, engineers employed a CAD model of a Fiat Mobi and applied electrical conductivity data to all the components based on data supplied by component suppliers and published data. They created low-impedance connections between metal components. They added this model to the solution domain and repeated the Maxwell simulation. The vehicle model caused the charge distribution to be distorted, and

strong fields were evident on sharp tips and elevated points of the vehicle. The probability of lightning striking any particular spot on the model is proportional to its electric charge. FCA and ESSS engineers confirmed that the antenna is the most likely area for lightning to strike a vehicle.



Pulse, modeled according to statistics of discharges, was applied to vehicle in transient simulation.

they applied a 45 kiloamp peak discharge into the vehicle. They also created a low-impedance return path from the ground back to the cloud.

The simulation results showed the electric currents and voltages on the exterior of the vehicle caused by lightning, and revealed the path through which these charges flow to ground. The simulation also showed the electric and magnetic fields created by these currents and the resulting currents induced on vehicle components, including the wiring harnesses. As expected, the highest currents were induced on geometrical features such as tips and edges. However, the effects of the geometry and conductivity of the vehicle exterior on the voltages and currents on the wiring harnesses required 3D transient electromagnetic simulation to unravel.

IMPROVING THE VEHICLE DESIGN

Because they could simulate the effects of a lightning strike, engineers were able to investigate the potential for design changes to reduce damage to the vehicle. For example, they plan to determine whether increasing the conductivity of high-resistance components such as tires and windshields would reduce the electric fields inside the vehicle. FCA will soon simulate components with different conductivities and then work with suppliers to see what improvements can be made. Engineers also plan to investigate changes in the wiring harness such as changing the number of turns per inch in twisted cables, using different types of shielding for the wiring harness, and installing different connection points between the shielding and the chassis.

There are no standards for protecting automotive electronics against lightning strikes, but the proactive engineers at FCA are using simulation to look for solutions to reduce its impact on automotive electronic control units, antennas and wiring harnesses. Simulation enables engineers to accurately predict the current generated in wiring harnesses and other vehicle components during a lightning strike, making it possible to evaluate potential design improvements at a fraction of the time and cost required for physical testing. ⚠

The antenna is the most likely area for a lightning strike.

