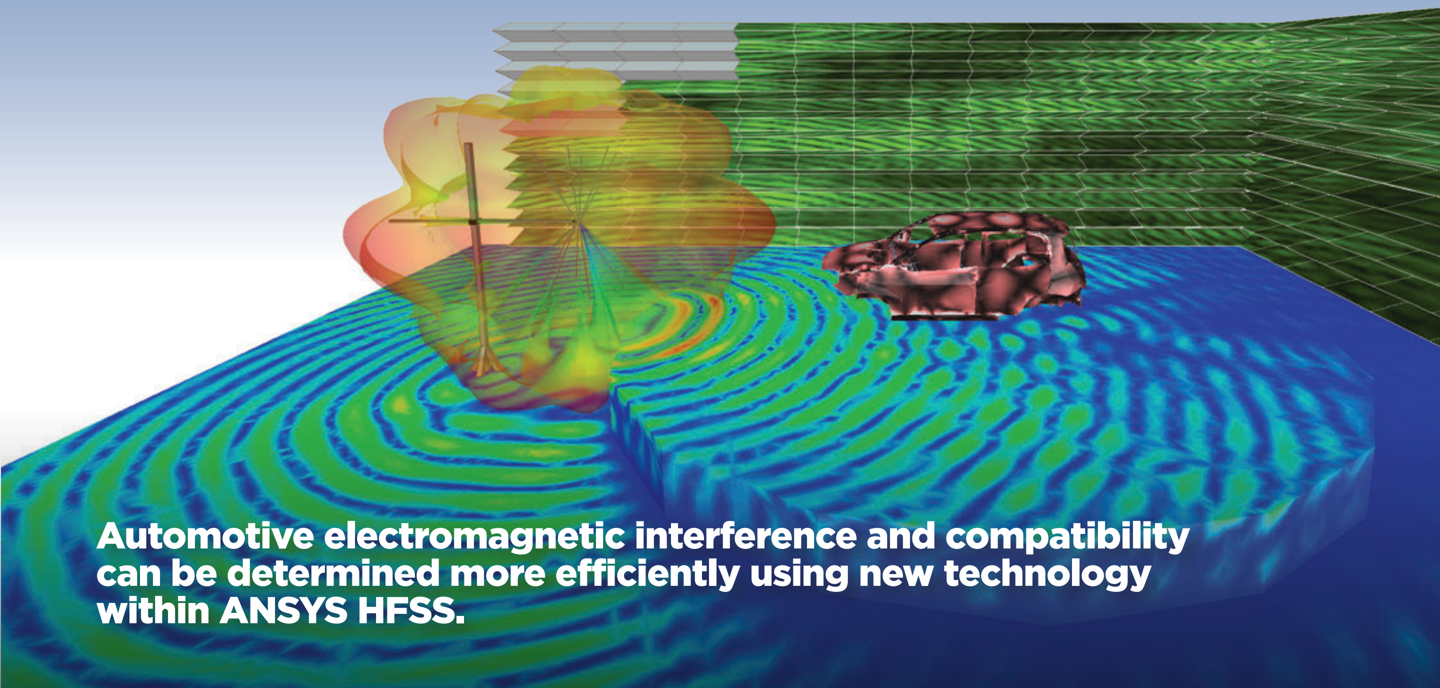
ROBUST ELECTRONIC SYSTEMS

TEST DRIVE FOR EMI



Automotive electromagnetic interference and compatibility can be determined more efficiently using new technology within ANSYS HFSS.

By **Arnaud Christophe Pierre Marie Colin**, Lead EMC Designer; **Artur Nogueira de São José**, EMC Engineer; and **Ana Carolina Silveira Veloso**, EMC Engineer, Fiat Chrysler Latin America, Betim, Brazil
Juliano Fujioka Mologni, Lead Application Engineer, ESSS, Brazil
Markus Kopp, Lead Application Specialist, ANSYS

Automobiles are fast becoming mobile hotspots. Components such as wireless links, multimedia devices, electronic control modules and hybrid/electric drives are continually being added to vehicles, which makes designing for electromagnetic interference (EMI) and electromagnetic compatibility (EMC) increasingly important. At Fiat Chrysler in Brazil, a team of engineers is certifying the complete product integrity by investigating potential EMI on its vehicles using ANSYS HFSS and full-vehicle testing.

Because electronics have been rapidly added to automobiles, a number of guidelines have been developed, including legislation, industry association standards and even regulatory limits that are specific to a particular automotive manufacturer. One of the earliest industry directives was issued in Europe in

As automobiles become mobile hotspots and electronic components are continually added to vehicles, designing for EMI and EMC becomes increasingly important.

1972 to deal with electronic spark plug noise; since then, many organizations have created a variety of standards specifically for the automotive industry.

Many standards, directives and regulations are designed with vehicle safety in mind. This ensures that all onboard systems continue to function properly during exposure to EMI and then return to normal, either automatically or by a manual reset operation after exposure. A major concern for Fiat Chrysler's engineers is the amount of wires a car now contains — as much as 5 kilometers per vehicle. While cabling is an obvious source of EMI, there are a number of other sources in modern vehicles that are packed with electronics. In addition, drivers introduce potential EMI sources in the form of mobile phones, tablets and Bluetooth®-enabled devices. Automobile manufacturers that create smart vehicles need to meet standards to reduce risk of failure.

Conventional EMI/EMC procedures and techniques are no longer appropriate for the latest generation of electronic devices and components. A few automotive standards have been developed that use laboratory tests in an attempt to reduce the probability of EMI occurring in vehicles. One important international lab-based standard is ISO 11451-2. This standard calls for testing a source antenna that radiates throughout the vehicle in an anechoic (echo-free) chamber; the performance of all electronic subsystems must not be affected by the electromagnetic disturbance generated by the source antenna.

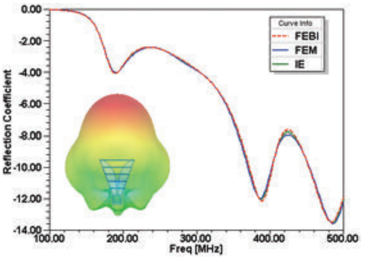
ISO 11451-2 is meant to determine the immunity of private and commercial road vehicles to electrical disturbances from off-vehicle radiation sources, regardless of the vehicle propulsion system (including hybrid/electric vehicles). The test procedure prescribes performance on a full vehicle in an absorber-lined, shielded enclosure, creating a test environment that represents open-field testing. For this test, the floor generally is not covered with absorbing material, but such covering is allowed.

Testing for the standard consists of generating radiated electromagnetic fields using a source antenna with radio frequency (RF) sources capable of producing the desired field strengths ranging from 25 V/m to 100 V/m and beyond. The test covers the range of frequencies from 10 kHz to 18 GHz. During the procedure, all embedded electronic equipment must perform flawlessly. This flawless performance also applies to the frequency sweep of the source antenna.

Physically performing the ISO 11451-2 standard test can be a time-consuming process that requires costly equipment and access to an expensive test facility. Numerical simulation can be a cost-effective, alternative means to reduce the product design cycle and its associated R&D costs. Full-vehicle finite element method (FEM) simulation has become possible within the past few years using the domain decomposition method (DDM), which was pioneered by ANSYS HFSS software. DDM parallelizes the entire simulation domain by creating a number of subdomains, each solved on different computing cores or various computers connected to a network. While DDM allows engineers to simulate entire vehicles, there is another approach available within HFSS for solving large electromagnetic structures: a hybrid finite element–boundary integral (FE-BI) methodology.

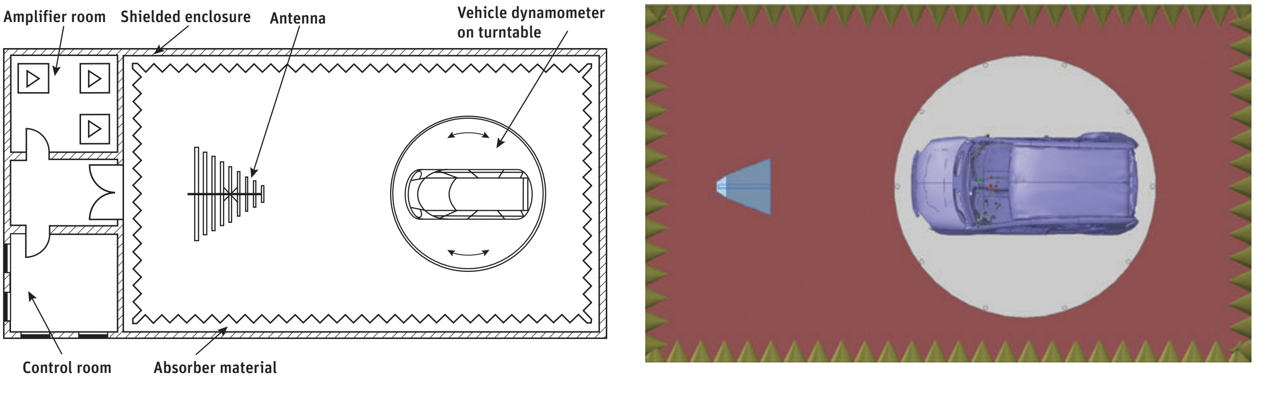
FE-BI uses an integral equation (IE)–based solution as a truncation boundary for the FEM problem space, thus bringing together the best of FEM and IE. This combination of solution paradigms allows Fiat Chrysler engineers to dramatically reduce the simulation's solution volume from that required by the FEM method. Because the distance from radiator to FE-BI boundary can be arbitrarily small, solution time is decreased, as is the overall computational effort.

To demonstrate the capability of the FE-BI methodology, the Fiat Chrysler team worked with ESSS, the ANSYS channel partner in South America, to conduct

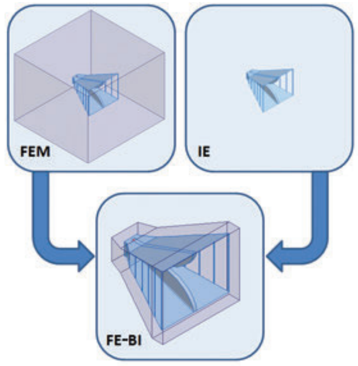


▲ A comparison of far-field behavior shows that the FE-BI method is accurate compared to traditional methods.

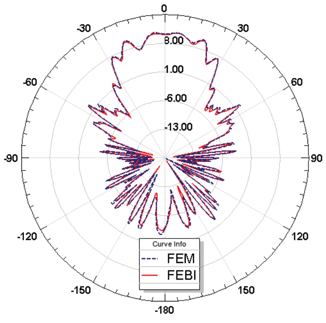
ELECTROMAGNETIC SIMULATION OF ANTENNAS INSTALLED INSIDE VEHICLES: AN AUTOMOTIVE EMC APPROACH
ansys.com/92emi



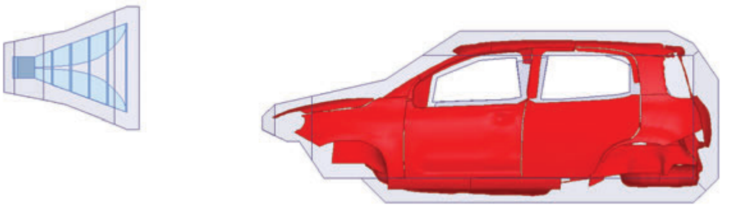
▲ ISO 11451-2 test apparatus (left). Virtual test chamber used for ANSYS HFSS simulation (right)



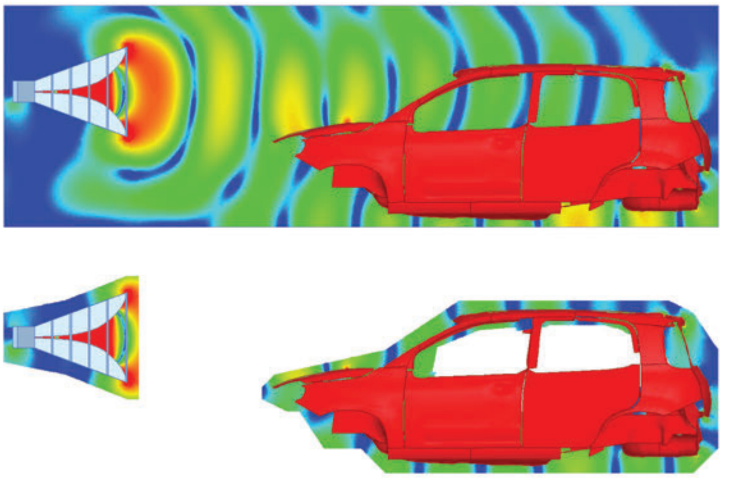
Comparison of FEM, IE and FE-BI models. The reduced size of the solution region when using FE-BI (as compared to traditional FEM or other numerical 3-D field solvers) leads to a faster simulation.



Antenna far-field pattern at Φ=90 degrees for the whole model



Two subregions were solved simultaneously using the HFSS FE-BI solver. The air region is shown in light blue, and the majority of the air volume has been removed.



The electric field on both the surface shell and a plane that bisects the solution volume of the vehicle for traditional FEM (top) and FE-BI (bottom) results

a full-vehicle simulation using the FE-BI capability. The team then applied the results to the ISO 11451-2 standard to determine EMI of an electronic subsystem. For the simulation, the team reduced the large air region in the test chamber to two much smaller air boxes that more closely conformed to the structures they contained. The surfaces of these air regions were located close to the antenna and the vehicle.

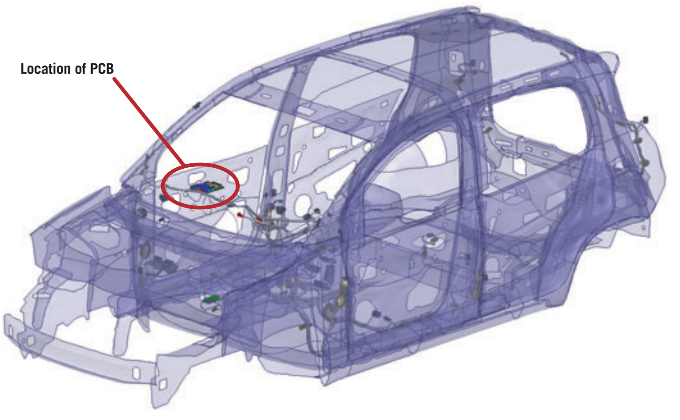
Fiat Chrysler engineers did not model the absorber elements in this simulation because the IE boundary in FE-BI is equivalent to a free-space simulation, which is the same as absorbing material used in a physical measurement. The total computation time of just 28 minutes represents more than a 10-fold speedup when compared to a traditional FEM solution. Additionally, the total amount of RAM required for the FE-BI simulation was 6.8 GB, which is also more than a 10-fold decrease compared to previous work using FEM.

Solution results using the FE-BI method showed that the predictions for the quantities of interest were in excellent agreement with those obtained using FEM. The electric fields calculated on both the vehicle's surface shell and a plane that bisects the car were very similar for both solution methods, as were the total far-field patterns of the entire model.

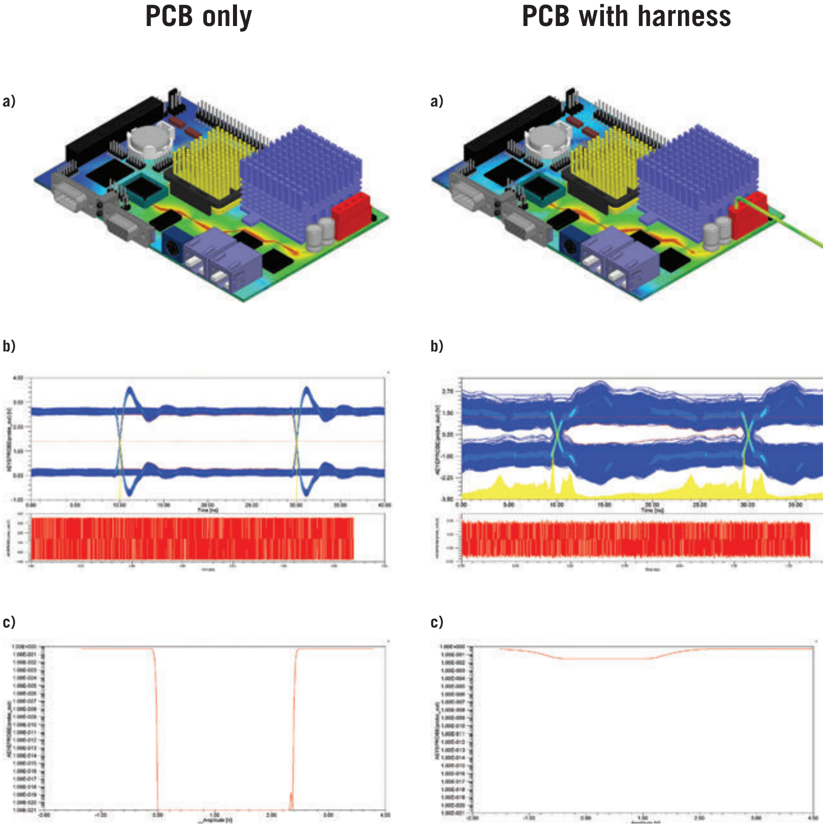
The FE-BI approach also can be used to test the immunity of embedded control unit modules. To demonstrate this capability, the engineering team introduced a printed circuit board (PCB) connected to the engine wiring harness into the simulation. The transmitted signal travels from a sensor, located at the bottom of the engine, to the PCB using a wiring harness that is routed around the engine. The wiring harness end is attached to the PCB using a red four-way connector. One of the four-way connector's pins is soldered to a trace that begins in the top side of the PCB on the connector side and then goes through a via to the bottom side, where it is connected to the microcontroller. In this case, the team analyzed only a single onboard diagnostic (OBD) protocol CAN J1913 signal.

The wiring harness plays a vital role in EMI because the harness can act as a radiation source. To better understand the effect of the wiring harness, ESSS engineers performed two simulations. The

The ANSYS HFSS FE-BI capability is clearly advantageous as a numerical technique to simulate a full vehicle according to automotive EMC standards.



▲ Location of PCB relative to vehicle



▲ Simulation of CAN J1939 signal in PCB alone (left) and in PCB with wiring harness (right): a) Electric field plot distribution. b) Eye diagram of received signal at microprocessor. EMI is observed when the harness is attached. c) Bathtub diagram for signal being received at microcontroller. The bathtub curve is greatly affected by the EMI source, with a final bit error rate of 1E-2. This means that one bit out of every 100 will be incorrectly interpreted by the microcontroller.

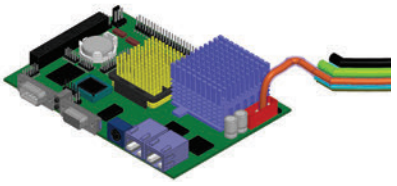
first included the PCB and wiring harness along with the chassis and source antenna. For the second simulation, the team removed the wiring harness, and the random CAN J1939 signal was applied directly into the PCB connector instead of at the sensor location at the bottom of the engine.

Using the FE-BI solver in HFSS, the team easily calculated the electromagnetic fields and the scattering parameters of the two simulations (with and without wiring harness). The simulations showed a resonance on the PCB when connected to the wiring harness. The frequency of this resonance is a function of the length of the cable attached to the PCB. When attached to the PCB, the harness increased the coupling between source antenna and PCB by more than 30 dB between 152 MHz and 191 MHz.

Finally, the engineers dynamically linked the 3-D electromagnetic model to the ANSYS circuit solver available in HFSS to simulate the CAN J1939 signal in the wiring harness and PCB. The frequency-domain field results produced by HFSS were seamlessly combined with time-based signals using ANSYS Designer software. In Designer, it is possible to specify the various signals that excite both the antenna and the wiring harness. For these simulations, the team set the antenna excitation to a constant 150 V sinusoidal signal, with a delay of 8 µs and a frequency sweep varying from 10 MHz to 500 MHz. The initial time delay was set to clearly see the effect of EMI on the transmitted signal. The team generated the CAN J1939 signal at the sensor end of the harness for the first simulation; for the second simulation, the signal was injected directly at the connector with no wire harness present. Simulation with the harness shows that the overall sensor system performance will be greatly affected by incoming radiation in the 152 MHz to 191 MHz band.

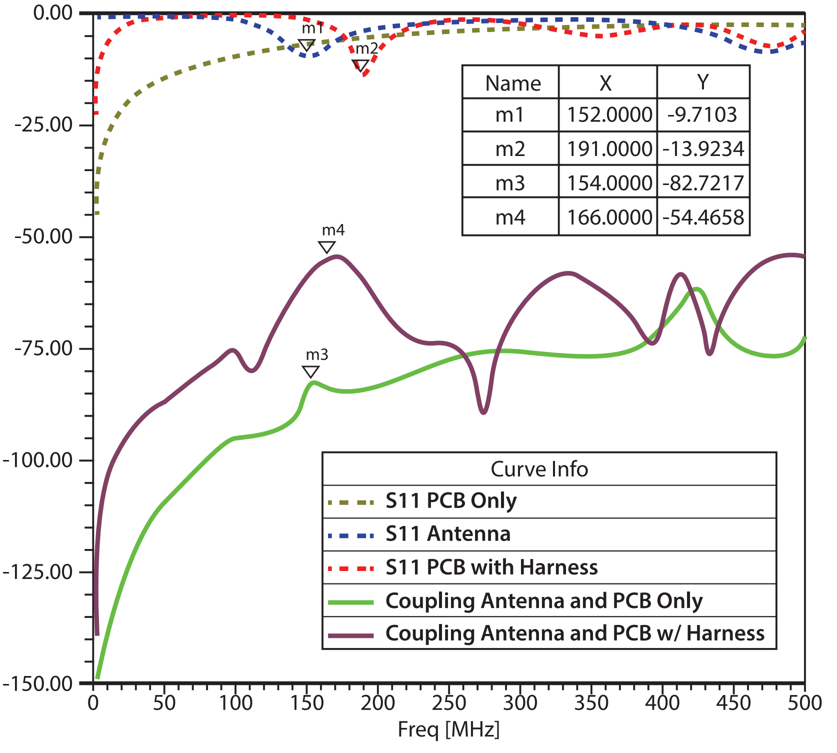
The ANSYS HFSS FE-BI capability is clearly advantageous as a numerical

Simulation allows for accurate what-if analysis to determine potential EMI issues caused by driver- or passenger-introduced electronic communications devices.



▲ Point where wiring harness attaches to PCB

technique to simulate a full vehicle according to automotive EMC standards. The FE-BI technique was over 10 times faster and required 10 times less computational effort than a traditional FEM simulation. As a result, EMI/EMC engineers can begin to simulate entire vehicles and their subsystems in virtual anechoic chambers to meet EMC and EMI standards. Using simulation also allows for accurate what-if analysis to help determine potential EMI issues caused by driver- or passenger-introduced electronic communications devices. It also leads to a better understanding of transient noise issues caused by the myriad of motors included in every vehicle.



▲ S-matrix with PCB, both alone and connected to wire harness