WHITE PAPER

Electromagnetic Modeling of Full Vehicles and Their Cables – Unique Ansys Capabilities

The paper examines the electromagnetic simulation problem of large platforms such as aircraft or land vehicles along with their internal data-carrying cables using Ansys EMC Plus. A combination of solvers is used to properly capture the electromagnetic behavior of the cables, co-simulate the platform body and its cables bidirectionally, import data from CAD and cable database software automatically, and properly model cable terminations (including imperfect ones). Competitor offerings are unable to perform all the above tasks, but EMC Plus offers the features and capabilities to support these requirements and ensure high accuracy of simulations against real-world test data.

/ Introduction

Manufacturers of automobiles and aircraft require full digital representations of their vehicles that allow for accurate electromagnetic simulation. In the automotive industry, there is a desire to simulate and predict the full vehicle electromagnetic compatibility (EMC) performance of a vehicle using digital designs, which can be performed months or years before vehicles are available for lab testing. In aerospace and defense applications, digital simulation is important for EMC, but it is also essential for designing to meet electromagnetic environmental effect (E3) requirements. This includes dramatic events such as lightning strikes, as well as more standard conditions such as operating in strong electromagnetic field conditions.

An important aspect of these digital simulations is how cables carrying signal traffic are handled, both from a digital engineering perspective and a numerical simulation approach. While there are many simulation products that claim to simulate cables, not every product has the features necessary to accurately model a full vehicle. As you consider a simulation product for full vehicle and cable electromagnetic simulation, consider the requirements below.

/ Requirement 1: Include all critical cables from the platform in the simulation

Modern vehicles contain thousands of individual conductors organized into hundreds of individual cable harness segments. Evaluating vehicle performance requires the inclusion of all critical cable conductors and harness elements. It is essential to select an electromagnetic modeling tool that can accurately include this large number of cables into the model.

Some electromagnetic modeling tools claim the ability to perform a full-vehicle simulation. However, other simulation techniques simply do not allow you to model such a high density and number of cables for a full vehicle.

Ansys EMC Plus addresses the challenge by using a hybrid technique. The structures of the vehicle are solved using the 3D finite-difference time-domain (FDTD) method of solving Maxwell's equations, which enables high accuracy and the ability to mesh complex geometries derived from CAD mechanical descriptions of the vehicle. FDTD is a "full-wave" method that includes no approximations other than discretizing the derivatives and setting up the magnetic and electric fields on a staggered grid description of the problem domain. The cables are solved using a technique called multiconductor transmission line (MTL) simulation. This technique takes advantage of the cable harness symmetry to provide a computationally efficient solution.

First, EMC Plus solves the 2D cross-section of the cables automatically with an electrostatic solver to calculate the inductance and capacitance matrices. This is combined with the resistance and conductance matrices to complete the inputs to the MTL simulation. Next, the 3D solver for the structures is co-simulated with the cable solver on the same grid.

The benefit of this hybrid technique is that you can use a much larger grid size for the vehicle structures. The cables are simulated with MTL such that extremely small features of the cables, such as shields, foils, braids, and jackets, are solved in a computationally efficient manner. Small feature-size accuracy is provided near the cables as a result, and the performance of larger grids is allowed everywhere else.

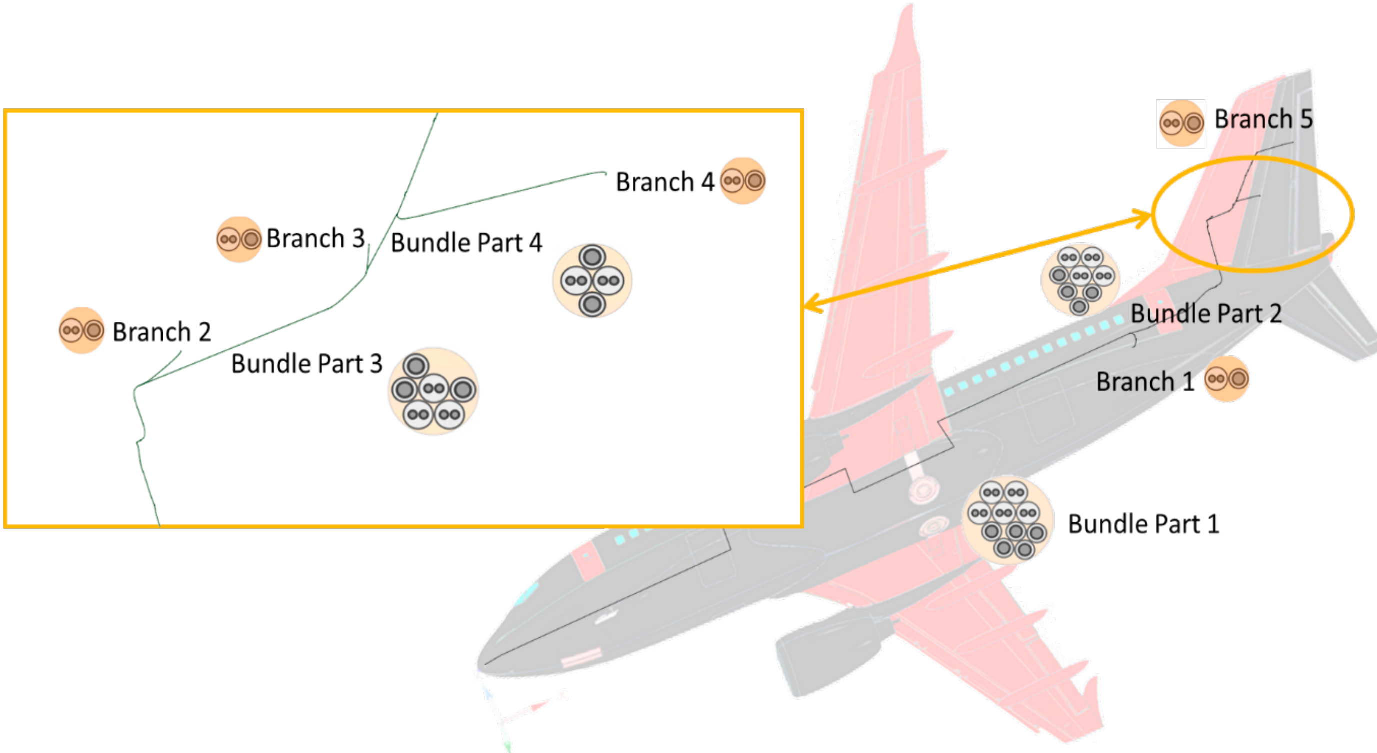

Figure 1. Ansys EMC Plus simulates the structures on a large grid and co-simulates the cables using a hybrid technique that can scale up thousands of individual conductors.

Including the specialized cable solver within the 3D model has a practical impact beyond simply the efficiency of the computational resources. This method of representing cables by dealing with the cross-section in 2D in a separate step allows more cables to be physically represented in a small region of space. In real vehicles, cables are densely packed against other cables near structures and components within the vehicle. Modeling such a high density of discrete geometric elements is not practical with traditional solvers that do not include a co-simulation with a dedicated cable solver.

EMC Plus enables accurate simulations of entire vehicles that contain thousands of individual conductors within hundreds of harness segments. We believe the number and density of cables in such simulations is 10 times higher than what is possible with other offerings. Further, the accuracy of this approach has been proven by comparisons between simulations of an entire vehicle and experimental measurements on the same vehicle. As an illustrative example, read the Ansys Advantage article "How Embraer Uses Simulation to Put Planes in the Air Faster."

/ Requirement 2: Consistently co-simulate cables and the platform

Accuracy in the selected simulation approach is a key requirement for electromagnetic design teams. There is a common but unfortunately inaccurate method of combining cable solvers and full-wave solvers. The connection between the solvers can be weak, involving two separate simulations and data exchange, or it can be strong, in which the solvers co-simulate with information moving back and forth at each time-step. The weak coupling method is known to be inaccurate, making this approach a poor choice for full-vehicle simulations.

As a key feature of Ansys EMC Plus, the cable solver (MTL) and the 3D structure solver (FDTD) are co-simulated on the same grid. Within the solver, both techniques have access to the electromagnetic fields, currents, and the impedance matrices. We sometimes refer to this approach as bidirectional coupling. In other words, electromagnetic fields and currents may couple from the 3D solution to the cable, from the cable to the 3D solution, and in both directions in the same problem. This tight integration between the two solvers is necessary for solution accuracy.

Unfortunately, not all commercial electromagnetic cable solvers perform analysis with a 3D field solution and the MTL in a self-consistent way with bidirectional coupling. Many tools utilize one-way coupling between the 3D field and the MTL cable solver. There are a couple of reasons why this solution is not optimal. Consider the following common scenario in which a vehicle is illuminated externally by fields that induce current on cables. The cables enter a shielded cavity and bring electromagnetic power into the cavity. The cables reradiate inside the cavity with the potential to impact nearby systems. Therefore, shielding simulations cannot be accurate in vehicles without bidirectional coupling.

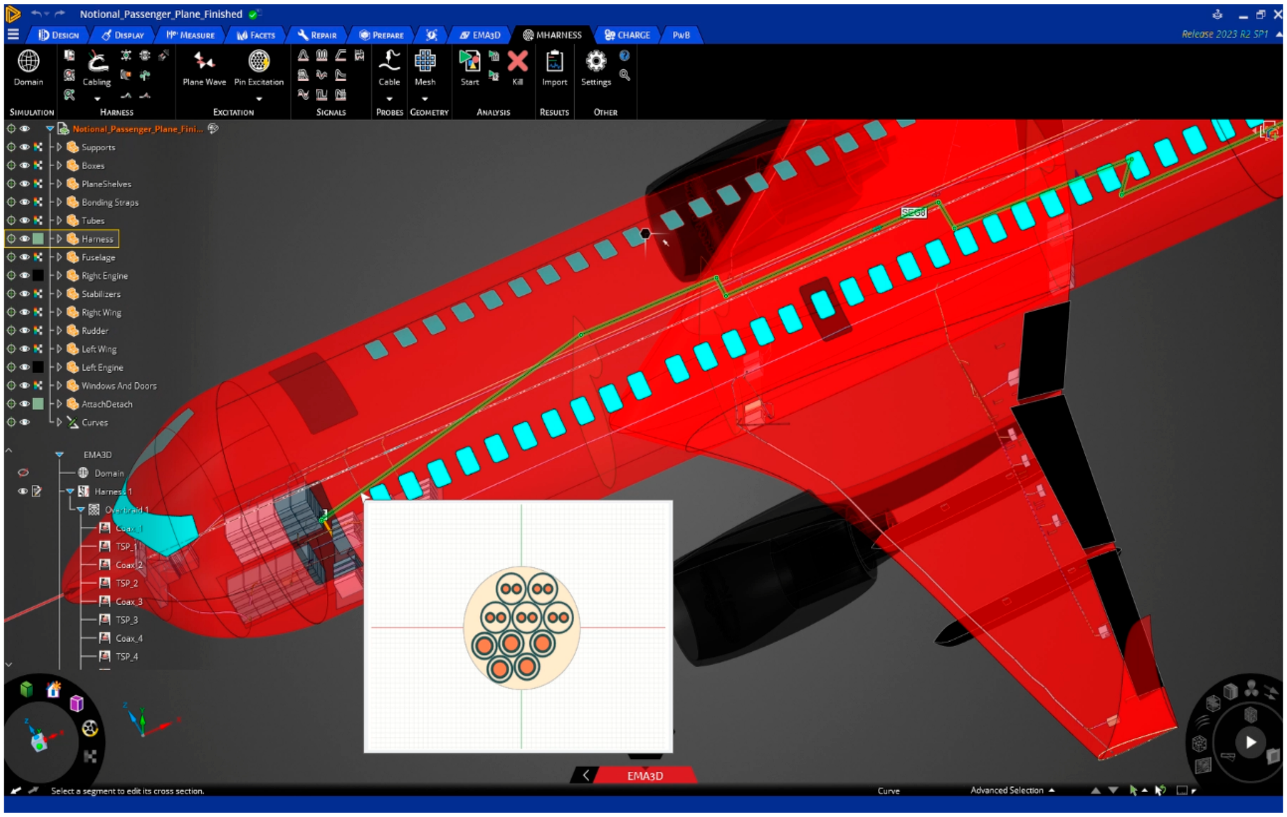

Figure 2. EMC Plus's 3D field solution and cable solver are both solved on the same grid and in the same binary, with shared field, current, and impedance matrix information.

Another way in which one-way coupling can be inaccurate is that the observed resonances of the simplified field coupling solution are much higher when the details of the cable harness are not included in a self-consistent way. This effect was shown in "The Necessity of Including Complexity to Model Wire Harnesses in a HIRF Environment" at the EUROEM 2012 conference in Toulouse, France. Without two-way communication between solvers, the results are over-predicted by more than a factor of 10.

As a result of these effects described above, engineers seeking to simulate entire vehicles must insist on a two-way, self-consistent coupling of cable solvers and 3D solvers.

/ Requirement 3: Automatically import information from cable database software and accurately fuse cables with mechanical designs

Digital engineering techniques are transforming product design. There are three sources of data that are of interest to full-vehicle simulation. Product life cycle management (PLM) systems contain information about the CAD design of the vehicle and tracks changes in the design as the product is developed and updated. PLM systems may also contain detailed materials information on the platform, which is essential in mapping electromagnetic properties for simulation.

Next, electrical wiring interconnect system descriptions of cables, whether within the PLM database or in specialized database software, are another necessary input. Specifically, the wiring diagram for connectivity, the gauge of conductors, and the types of shields and jackets are key details specified in these database systems. In some cases, the physical routing of the cable harness path in 3D is stored in the mechanical CAD. In other cases, it is present in the cable database software.

When it comes to selecting an electromagnetic simulation solution, it is essential that your tool enables the fusion of the disparate data described above into a single problem description. Otherwise, the engineering effort to manually assemble and correlate the inputs becomes an insurmountable task.

EMC Plus is up to the complex task of fusing the various inputs of geometry, materials, and cable descriptions into a working model. The import wizards are mature and easy to use. Automating the process takes something that would have taken months or years and makes it possible in a few hours. The connection to the digital engineering thread is what makes for transformation leaps in the amount of system complexity that may be reasonably analyzed.

We have heard from customers that the time taken to specify cables accurately in the product is far shorter than the leading competitive tool. In one case, an aircraft manufacturer calculated the engineering time to add all critical cables using the leading competitor's software as three person years. The aircraft manufacturer selected EMC Plus and prepared the same design in six weeks. Therefore, the capability of EMC Plus is not just a little better; it is transforming what is possible using digital engineering for full-vehicle electromagnetics.

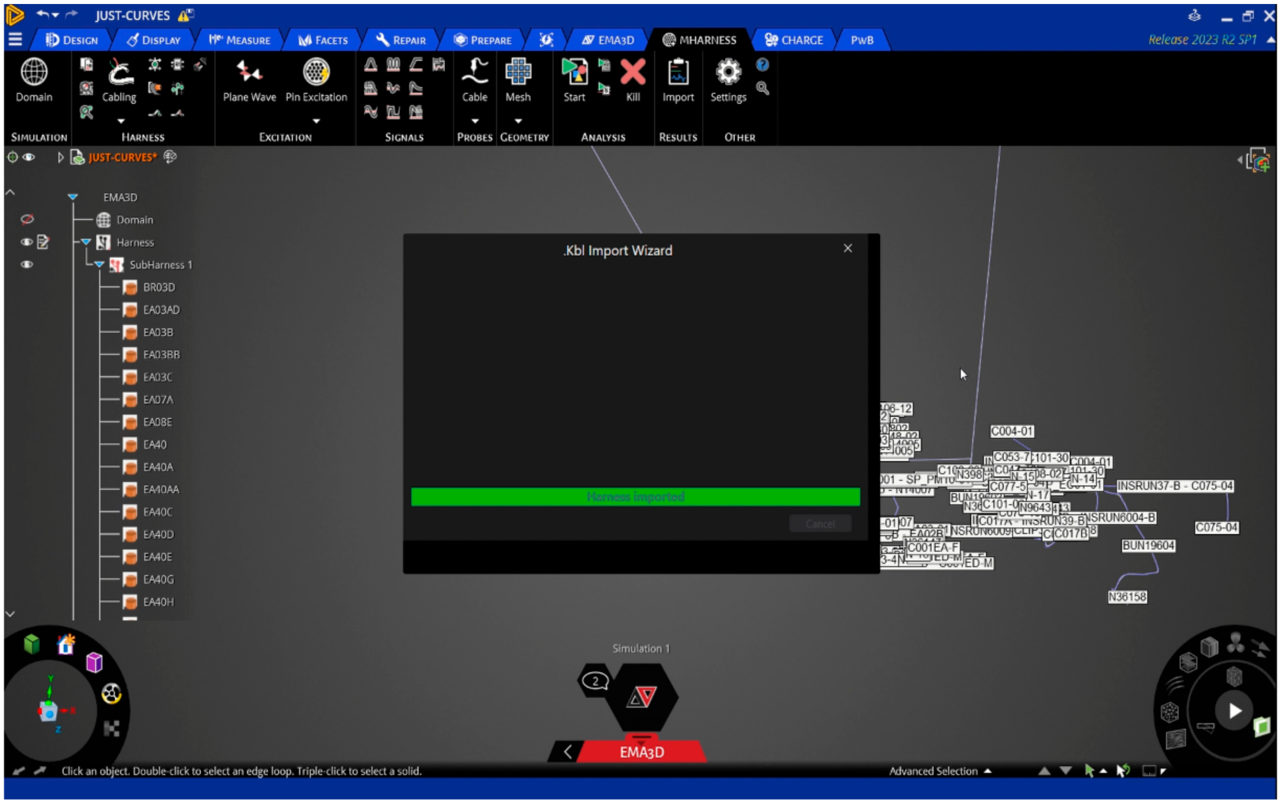

Figure 3. EMC Plus can automatically import cable database software wiring diagrams and map each segment to the correct 3D location.

/ Requirement 4: Allow conductors to emerge from shields

The next requirement is the capability to support accurate cable modeling under common circumstances. When designing a cable interconnect system, the goal of that system is to have an electrical connection between electronic devices that span some distance. When shielding is introduced around the conductors, that shielding must be removed from the conductor before it is in contact with the electronic system — usually by a connector on a printed circuit board. However, in the original formulation of MTL cable simulation, shielded cables must always remain shielded. There was no way to model the behavior of connecting conductors as they function in real systems.

For cable shields to have the best shielding performance, they should have a low-impedance, 360-degree termination to the enclosure at each end. On some platforms, this type of shielding is achievable. However, real vehicles often have compromises in the type of shielding in some way. And don't forget — the original MTL cable formulation did not allow for imperfectly terminated shields.

The development team behind EMC Plus overcomes this limitation of MTL by utilizing self-consistent co-simulation with the 3D solver. The tool allows conductors to emerge from shields to terminate on printed circuit boards. Further, shields can be dropped in the middle of the cable, terminated with a short wire called a "pig tail," or otherwise be imperfectly terminated. Only by using fields and currents in both the full-wave and the MTL solver is this simulation capability possible.

To our knowledge, no other competitive tool has this same feature. Without the ability to break conductors out of shields and realistically terminate shields in a finite impedance, no real vehicle with cables can be accurately simulated in the electromagnetic environment. Therefore, this is an essential capability when choosing a simulation product.

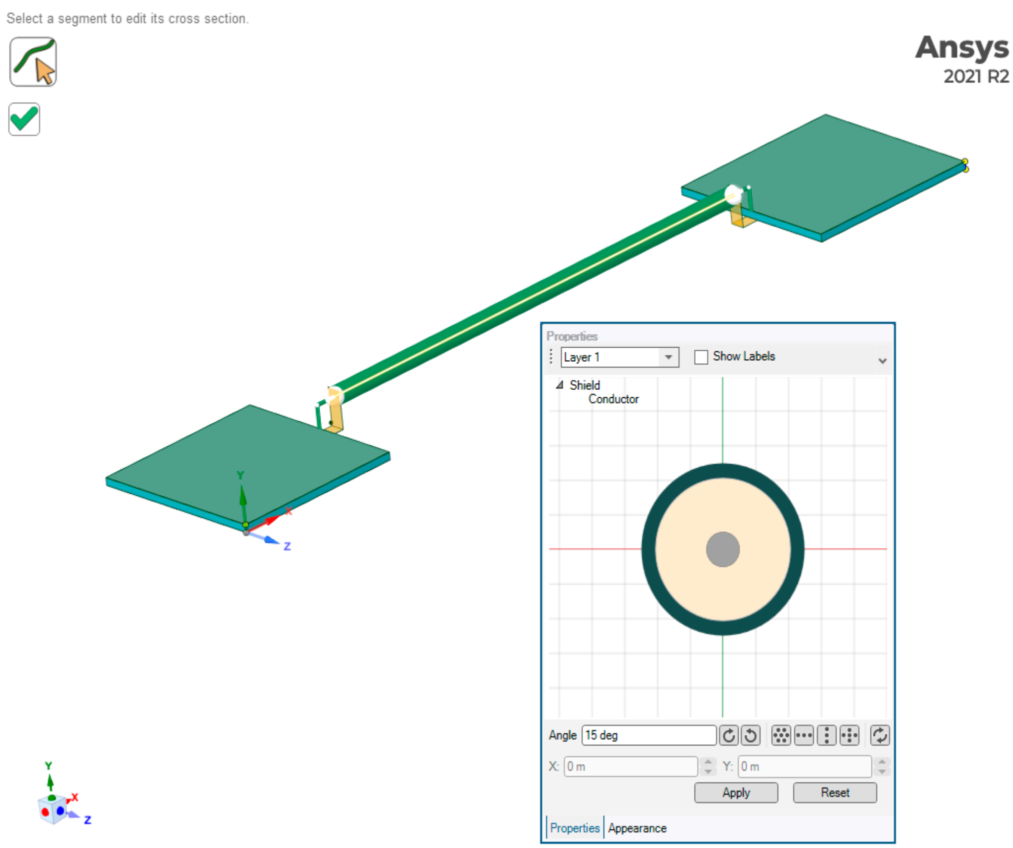

Figure 4. EMC Plus allows conductors to break out of shields for realistic termination and retain simulation accuracy. Though a seemingly simple scenario, this is not supported by traditional cable simulation methods.

/ Final Thoughts

Computational electromagnetics is a cutting-edge field in electronic design automation (EDA) and CAD. The tools that employ the sophisticated numerical methods and solvers at the heart of electromagnetic simulation are in high demand.

But these tools are not all alike. Being able to co-simulate a large platform such as an aircraft or ground vehicle in conjunction with its internal signal cables and cable bundles is an essential capability in supporting developers creating tomorrow's aircraft, spacecraft, and automobiles. But choosing an appropriate electromagnetic simulation tool is gated by the simulator's ability to model and simulate such targets both rapidly and accurately, as well as readily employ data from other software.

To learn more about the unique capabilities of Ansys EMC Plus, click here.

ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724-746-3304
ansysinfo@ansys.com

When visionary companies need to know how their world-changing ideas will perform, they close the gap between design and reality with Ansys simulation. For more than 50 years, Ansys software has enabled innovators across industries to push boundaries by using the predictive power of simulation. From sustainable transportation to advanced semiconductors, from satellite systems to life-saving medical devices, the next great leaps in human advancement will be powered by Ansys.

Visit www.ansys.com for more information.