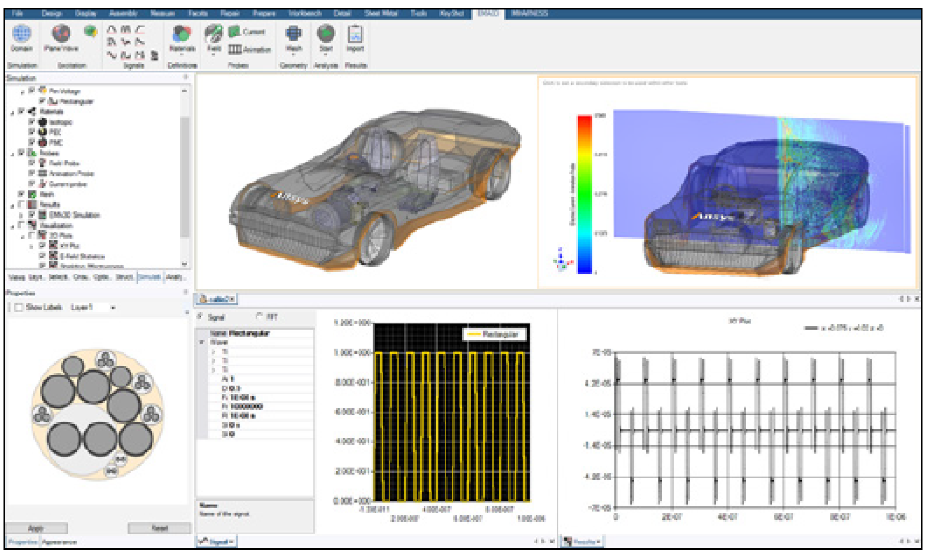
WHITE PAPER

How to Build a Virtual Electromagnetic Test Environment for Aerospace and Automotive Platforms

This white paper describes how to build a virtual test environment to support electromagnetic compatibility (EMC), radio frequency interference (RFI) and electromagnetic environmental effects (E3) design and verification.

"Generally, simulation tools provide more extensive means to rationalize threat level predictions than by using development testing alone, but also more extensive means to evaluate specific design features."

David Lalonde
Engineering Professional / Bombardier



A full-vehicle virtual EM test environment helps you design and certify your product to EM environments and requirements while saving time and costs.

/ Introduction

A full electromagnetic (EM) model of vehicles is essential for safeguarding the electromagnetic compatibility (EMC) of the system. Testing is typically performed at the unit level. Testing of the integrated vehicle must occur late in the program at a time when major changes in designs are not possible. Simulation assesses designs and ensures system-level compatibility early in a development or sustainment program.

This white paper describes how to build a virtual test environment to support EMC, radio frequency interference (RFI) and electromagnetic environmental effects (E3) design and verification. This process has been proven to save more than $1 million compared to the equivalent approach based solely on testing. The workflow is demonstrated using the electromagnetic simulation environment of Ansys EMA3D Cable. EMA3D Cable is a full-wave finite-difference time-domain (FDTD) electromagnetic solver that includes a multi-conductor transmission line solver for cables integrated within the FDTD geometry. EMA3D Cable is well-suited for simulation of complex platforms that include electrical wiring interconnect system cable harnesses.

1 D. Lalonde, J. Kitaygorsky, W. Tse, S. Brault, J. Kohler, C. Weber, "Computational Electromagnetic Modeling and Experimental Validation of Fuel Tank Currents for a Transport Category Aircraft" 2015 International Conference on Lightning and Static Electricity, Toulouse, France.

Virtual Electromagnetic Testing Fundamentals

One important aspect of the virtual environment that drives value is EM model reuse. The same geometric model may be used for multiple environments and requirements. The proliferation of product lifecycle management (PLM) systems and the use of three-dimensional (3D) computer-aided design (CAD) representations mean that EM engineers have ready access to their vehicle's geometry. An important advance is that modern EM simulation platforms, such as EMA3D Cable, allow for quick and efficient conversion of 3D CAD to an EM model of the entire vehicle. Thus, EM teams can maintain a virtual EM test environment that is traceable to CAD/PLM and is useful in predicting the integrated vehicle performance with respect to several EM requirements and environments. Examples of common EM virtual testing tasks include:

- EMC requirements per MIL-STD-461, DO-160, CISPR 25 or ISO 11452-2.
- E3 requirements for lightning SAE ARP5415 or ARP5416.
- E3 requirements for high-intensity radiated fields (HIRF) per SAE ARP5583.
- Electromagnetic interference (EMI) and intra-system compatibility of the platform.
- RFI for platforms including pattern distortion and source/victim interference.

The virtual environment is useful in many phases of vehicle development and sustainment. In many cases, the final verification testing on the platform remains many months or years in the future. However, compatibility requirements must be established early in the program lifecycle. The full-vehicle model is a way to determine the unit requirements that can be shared with vendors or design teams.

As the vehicle approaches integration or an upgrade in sustainment, there are often units that cannot meet requirements, leading engineers to request waivers or deviations to requirements. The full-vehicle model is helpful in determining the level of tailoring that is acceptable in order to maintain compatibility and establishing a low-risk path to meeting vehicle-level requirements.

In some cases, simulation may be used for certification. In fact, simulation was the certification basis for the MD-90 aircraft lightning indirect effects. EMA3D Cable has been useful in reducing full-vehicle testing. In these cases, a rigorous validation program is typically required. However, the benefit in schedule and cost for current and future programs can be substantial because the validated simulation may be modified and used as a certification basis for future derivatives.

Capturing Platform Details and Configuration Control

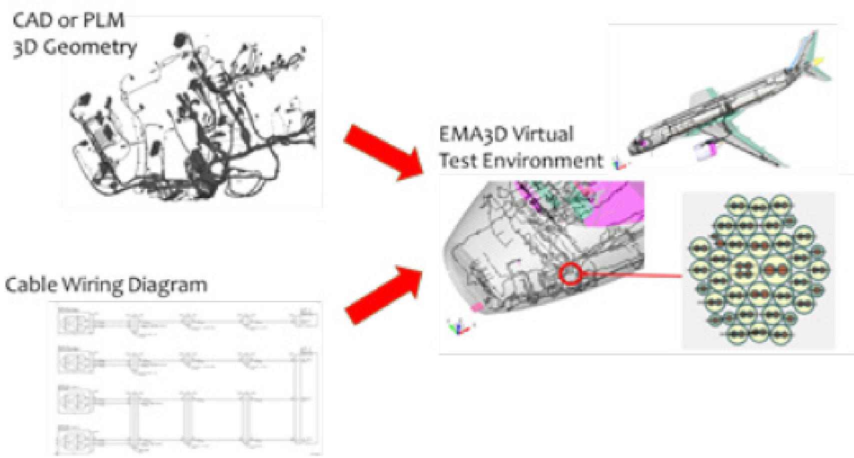
PLM, 3D CAD and other engineering databases are critical sources of information for the design and properties of vehicles. For EM engineers, other databases include descriptions of the electrical wiring interconnect system cables or details of the radio frequency (RF) system components.

Efficient conversion of the vehicle design from CAD and other sources to the EM virtual test environment is critical. EMA3D Cable has tools to make the transition as smooth as possible, with the ability to import all major CAD formats. EMA3D Cable has a fast and efficient mesh engine that allows for simulation without extensive CAD cleaning or preparation for simulation. Material properties can be quickly assigned in bulk using existing CAD component hierarchy trees.

---

2 T. He, B. Sherman, B. Nozari and T. Rudolph, "Time domain finite difference validation for transport aircraft lightning induced effect studies", IEEE 1995 International Symposium on Electromagnetic Compatibility, Atlanta.

The configuration control process utilizes CAD, PLM and other sources to document all virtual test model components, properties and assumptions. Parameters captured during configuration control are easily translated to material property assignments in EMA3D Cable.

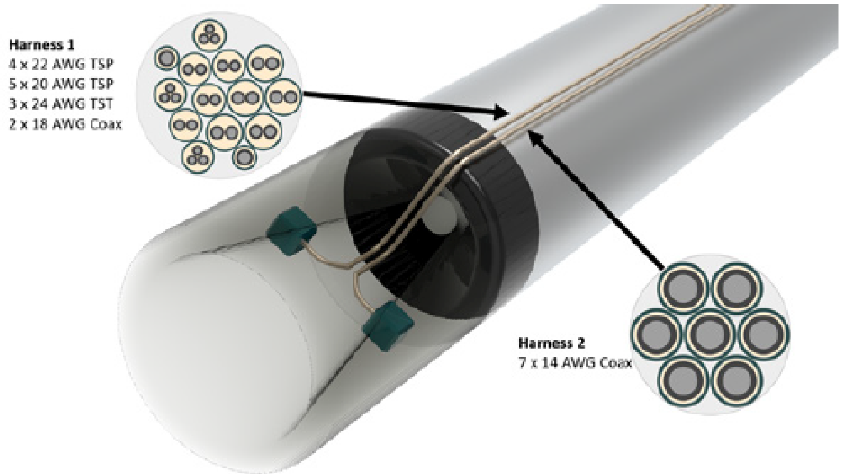


Design information from CAD, wiring diagrams and other sources are efficiently converted into an EMA3D Cable virtual test environment model.

/ Cable Modeling and Thin Material Properties

EM engineers know that small details can make a large impact on EM performance. The tiny conductors of a braided shield protect the inner conductors from unwanted EMI. Thin sheets of expanded copper foil protect surfaces from lightning. Thin, anti-corrosion surface passivation limits electrical bonding. Fortunately, simulation platforms such as EMA3D Cable are well-suited to allow engineers to add small features to virtual test environments without requiring time-intensive geometry modifications.

EMA3D Cable can model complex electrical wiring interconnect system cables that have over-braids, shields, multiple conductors, branches and terminations. The workflow allows engineers to specify the 3D routing of the cables from the CAD document. Then, the engineers can specify the shields and conductors from the wiring diagram. Most vehicle-level CAD drawings represent cables as hollow tubes that show the path of the cabling, but don't include the conductors or braids. Wiring diagrams or wiring databases contain the internal conductor and shield locations. EMA3D Cable allows engineers to specify the harnesses using the same two-step process. It includes a database of shield transfer impedance, which is a way of specifying shielding effectiveness. The 3D and multiconductor transmission line solver co-simulate to give the overall vehicle response, which has proven to be accurate compared to testing for full-vehicle scenarios. EMA3D Cable's workflow to create the 3D and cable details in the model is very fast. Its mesh engine does not require extensive CAD cleaning or preparation. Incorporating cable details is made easy with a database of common cable types. Measurements of cable shield performance is built in. Engineers can create models of entire vehicles in a reasonable time period, which would be impossible with other simulation platforms.



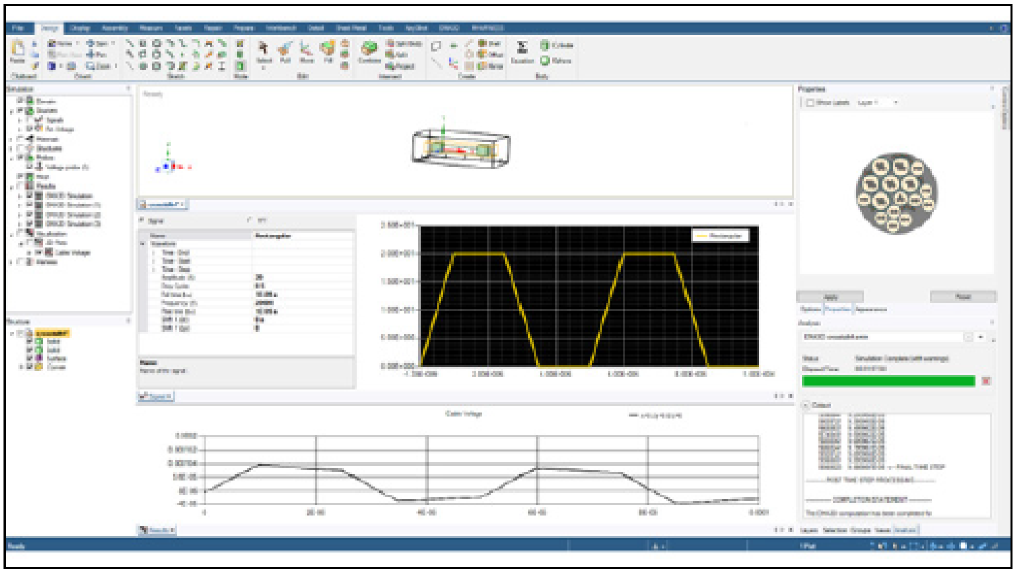
Small features can have a big impact on EM performance. EMA3D Cable can model cable harness shields with a simplified but accurate representation that saves time in building the virtual environment.

Another unique feature of EMA3D Cable is the ability to quickly handle small features with accurate sub-model representations. EMA3D Cable allows for specification of thin and complex model features with other simplified representations. Complex fastener rows that specify a mechanical joint between skin panels and underlying structure do not need to be directly modeled. Rather, they can be specified as a single line in the virtual test environment. EMA3D Cable allows for the seam transfer impedance to specify the seam or joint EM performance, thus simplifying the modeling effort. The seam transfer impedance may be determined for a certain joint type experimentally or using a simulated sub-model. Once this value is measured or analyzed, it may be used and reused in a vehicle simulation repeatedly whenever the same joint style is used. EM engineers maintain seam and joint databases for the types of interfaces their products may routinely contain.

/ Interpreting Results and Optimizing the Design

When the model is imported, the material properties are assigned and the small features are specified, the virtual test environment is ready to provide results. Radiated and conducted testing is supported in both susceptibility and emission formats. If there is a failure the engineer can modify the design and run the simulation again. They can provide confidence that a future real-world test will be successful with low risk. They can determine if a vendor's requirement can be safely relaxed without impacting compatibility of the vehicle to optimize mass or cost.

An example of EMA3D Cable's virtual test environment is shown below. The 3D CAD is in the top-middle view. The 3D CAD hierarchy tree is in the lower-left. The cable pin and shield cross section is in the top-right. The center box shows a voltage stimulus on a twisted-pair conductor. The resulting voltage induced on another conductor in the cable bundle is shown in the center-bottom. The hybrid 3D and multi-conductor simulation took two minutes.



EMA3D Cable virtual electromagnetic test environment to evaluate the level of EMI crosstalk.

/ Case Studies and Validation

Comparing simulation to experiment can result in validation of an EM virtual model for a platform. Once the validation is complete and successful, the same model may be reused in sustainment or upgrades of the same or future similar platforms. EMA3D Cable has a long heritage (MD-90) and is currently the most advanced software platform (CSeries , E-190) in the use of simulation to understand vehicle-level electromagnetic effects. The accuracy of simulation compared to test of full vehicles has been proven and has been published in the public literature. Contact EMA for copies of the publications.

/ Summary

Virtual test environments are an important tool to support EMC, RFI and E3 design and verification. Ansys EMA3D Cable is an electromagnetic simulation platform to create virtual test environments. Details from PLM, 3D CAD and other engineering databases provide configuration-controlled model inputs. Thin material features and cable harnesses are modeled using special algorithms in EMA3D Cable to allow for rapid and accurate specification. Engineers may reuse the same geometric simulation model for multiple electromagnetic requirements and environments. The results of EMA3D Cable virtual simulations of full vehicles compared to electromagnetic tests of the same vehicle show high correlation. Engineers may use the results as a method of verification, to determine the requirements early in a program, or to optimize the vehicle design.

4 T. He, B. Sherman, B. Nozari and T. Rudolph, “Time domain finite difference validation for transport aircraft lightning induced effect studies”, IEEE 1995 International Symposium on Electromagnetic Compatibility, Atlanta.

5 D. Lalonde, J. Kitaygorsky, W. Tse, S. Brault, J. Kohler, C. Weber, “Computational Electromagnetic Modeling and Experimental Validation of Fuel Tank Currents for a Transport Category Aircraft” 2015 International Conference on Lightning and Static Electricity, Toulouse, France.

6 C. Weber, J.A. Mariano, R. Freire, E. Durso-Sabina, “Validation of Numerical Simulation Approach for Lightning Transient Analysis of a Transport Category Aircraft”, 2019 International Conference on Lightning and Static Electricity, Wichita, Kansas, US.

ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com