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EMA E3 Certification Services: Business Case

Abstract

EMA has achieved success over the past thirty-five years by bringing high-fidelity simulation techniques to certification programs at major primes and major civilian/military aviation integrators. In this document, we describe some of the success stories from projects that have non-proprietary elements.

Table of Contents

Past EMA Customer Success Stories

Case Study 1: McDonald Douglas MD-90

Figure 1. EMA helped Douglas Aerospace save $1.6 M on the MD-90 indirect effects certification.

The first known application of the 3D finite difference time domain (FDTD) technique (EMA's FDTD code) for civilian certification of a complex transport aircraft occurred on the MD-90. In this project, simulation was used to determine the induced lightning transients at avionics box cable interfaces (indirect effects transient control levels). The simulation approach was validated using existing experimental data obtained for certification of the MD-80 program. This validation was accepted by the FAA so that the need for full-scale testing was eliminated.

The group noted that the simulation approach, including the verification experiments and analysis costs, were much lower than the cost to build the same number of physical models of reasonable size and perform the direct effects testing. The savings were estimated to be at least $1.5 M ($2.2 M adjusted for inflation).[1]

Since that time, the FDTD approach has become common for indirect effects qualification programs. EMA's codes have been used on a number of these programs and have achieved a high level of acceptance in the aerospace certification community. EMA's flagship FDTD product, EMA3D, is listed in SAE ARP 5415 as an acceptable method of determining indirect effects transients at avionics interfaces.

This example is from a few years ago; however, we note that the financial impact is still relevant today for these reasons:

- The test samples required and standard test procedures have not changed in this time frame. Therefore, the inflation-adjusted cost savings and program delay reductions will be similar for contemporary projects in comparison to the associated simulation-aided design approach.
- EMA's recent customers have achieved significant cost savings in projects; however, EMA is prohibited from releasing the financial/technical details due to proprietary and contractual restrictions.

[1] T. Rudolfph, B. D. Sherman, T. He, and B. Nozari, "MD-90 Transport Aircraft Lightning Induced Transient Level Evaluation by Time Domain Three Dimensional Finite Difference Modeling", 1995 International Aerospace and Ground Conference on Lightning and Static Electricity, Williamsburg, VA, USA

- Simulation-aided design approach has become standard practice for lightning and HIRF programs in recent years for aerospace integrators in the government and commercial sector in recent years.

Case Study 2: SAAB JAS 39 Gripen

Figure 2. EMA helped SAAB Aerospace save $9 M on the JAS 39 Gripen fuel tank direct effects certification.

One of the greatest challenges in certifying aircraft to the direct effects of lightning is protecting the fuel tanks from ignition. This task is complicated by the proliferation of carbon fiber composite materials. The SAAB JAS 39 Gripen has a carbon fiber wing and fuel tank.

In order to save cost compared to the corresponding testing program, SAAB chose to partner with EMA to prepare and validate simulations of the wing box fuel tank. EMA provided on-site simulation and early test design support. The simulation and experimental validation of the approach required about $1 M to complete. They estimated that the corresponding test program of building a full wing, testing and interpreting the results would cost on the order of $10 M.[2] This is a savings of $9 M ($16.8 M adjusted for inflation).

As a result, fuel tank certification efforts in the lightning environment are now routinely supported by FDTD simulation tools. EMA's codes are again a popular choice for this application for many aerospace integrators. At the end of this document in "EMA Experience in Certification and Qualification", EMA lists select current projects.

Case Study 3: Verification of Simulation Accuracy for Composite Materials

In a recent paper written by two EMA scientists in collaboration with Nobuyuki Kamihara and Koji Satake of **Mitsubishi Heavy Industries** and Kazuo Yamamoto of **Kobe City College of Technology**, we report on some experimentally-verified methods of simulating the complex, anisotropic current distribution pattern in carbon fiber-reinforced polymeric composites.[3]

Time-domain finite-difference (FDTD) models have been used extensively in the analysis of lightning attachment to an aircraft for both direct and indirect effects. Typically, these numerical

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[2] B. Wahlgren, M. Backstrom, R. Perala, and P. McKenna, "The Use of Finite Difference Electromagnetic Analysis in the Design and Verification of Modern Aircraft", 1989 International Conference on Lightning and Static Electricity, University of Bath, UK

[3] J. Kitaygorsky, J. Elliott, N. Kamihara, K. Satake, and K. Yamamoto, "Modeling the Effects of Anisotropic Material Properties on Lightning-Induced Current Flow in Structures Containing Carbon Fiber Reinforced Plastic", 2009 International Conference on Lightning and Static Electricity, Pittsfield, MA

simulations have used a simplified isotropic “bulk conductivity” algorithm in simulating the EM response of materials such as CFRP. However, close examination of actual current flows reveals that both the anisotropic nature of CFRP and the details of its connections to other metallic conductors need to be accounted for. This has been observed in several different sets of measurements using either CW current drive or Component A current pulse injection. To understand the measurements, a set of numerical models have been constructed to yield results for comparison to the test data. This series of models uses CFRP numerical models of increasing sophistication and complexity. Model and measurement results have been compared to determine the level of model complexity required in typical structural configurations

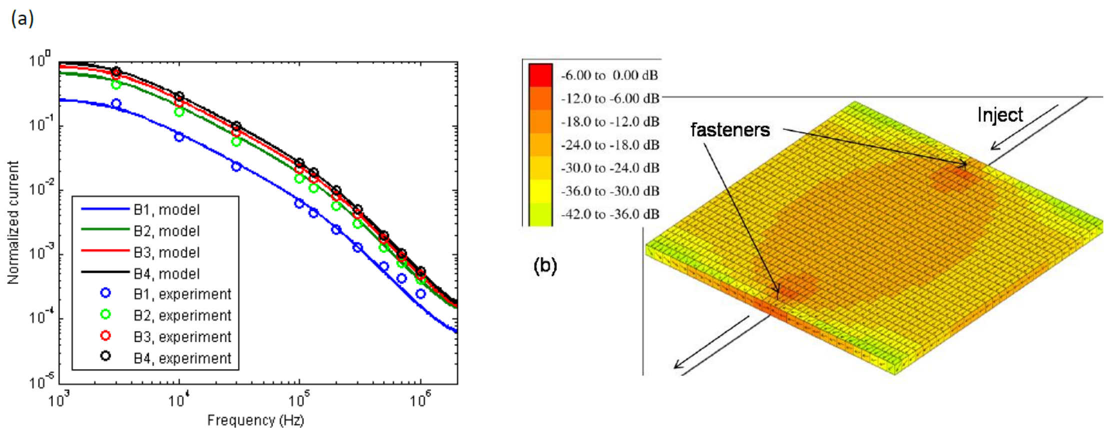

Figure 3. (a) Model and experimental results comparison for cw injection into the DCF sample, and (b) surface currents representation from the EMA3D model.

We found good agreement between the EMA3D model and the experimental measurements in composite materials (figure 3) as well as in an aluminum sample. The paper goes on to determine the proper way to model composite materials including some simplifications that allow for fewer layers than the number of layers in each composite panel that allow for shorter simulation times with the same degree of accuracy.

Case Study 4: Regional Jet Fuel System Verification

EMA is currently involved in assisting a major regional jet manufacturer in qualification of their airplane to lightning for FAA and EASA. Our work has involved indirect effects modeling to determine the transients induced on avionics interfaces for qualification testing using EMA3D software tools. In addition, we have assisted in direct effects modeling of the wing fuel cell to prevent sparking and failure during a lightning event. Our work has resulted in a better design of the fuel cell system along with complete avionics pin transient levels for the downstream vendors.

Further, we have verified that the EMA simulation approach is valid. The customer designed a simplified center wing box. EMA performed simulation of the wing box. The results from the testing were compared to measurements at Lightning Technologies, Inc. The close comparison allows for the use of the verified simulation approaches to model the actual center wing box.

Case Study 5: NASA/Lockheed Martin Crew Exploration Vehicle Lightning Certification

The Crew Exploration Vehicle (CEV) is NASA's new human-spaceflight effort to take astronauts out of low-earth orbit to the moon and beyond. However, it must be qualified to the lightning and other EM environmental hazards in the same manner as commercial aircraft. EMA is currently on contract to Lockheed Martin for the development and qualification of the CEV in lightning and other EM environments.

EMA prepared qualification plans for the lightning environment of the CEV during launch and reentry. EMA developed the zoning and attachment locations for lightning.

EMA successfully prepared simulations and trade studies to aid designers and EMC engineers to understand the actual transients that will be experienced in the lightning environment. In addition, we simulated the anticipated fields during lightning strikes at multiple vehicle locations and the lightning protection system at Kennedy Space Center. EMA has also determined the risk imposed by charging of the vehicle from space plasmas.

Case Study 6: Missile Defense Agency/Orbital Sciences Ground Based Missile Defense Interceptor Lightning/HEMP Certification

The ground-based missile defense boost vehicle is a critical element of the US missile defense system that provides the capability to engage and destroy intermediate- and long-range ballistic missile threats in the midcourse battle space to protect the US homeland. The boost vehicle must be qualified to the lightning and HEMP environments.

EMA was brought in to teach the design team the elements necessary to complete lightning and HEMP certification as well as perform simulation and test services. EMA provided on-site support in the initial years. EMA prepared detailed, 3-D models of the entire vehicles and have simulated lightning and HEMP environments. In addition, we developed harness models that determine the transient induced from each environment for each avionics pin interface in each vehicle. We have applied these transients in SPICE models of the actual circuits to determine whether the vehicle can operate-through the transient and plan for the appropriate TPD to harden each piece of equipment.

Business Justification

Below are general advantages that indicate qualitatively that integrators can reduce costs and program risk during the design phase of their lightning and HIRF certification programs by utilizing EMA's EMA3D simulation-aided approach. Some of the major factors include:

1) **Early specification of accurate interface control levels for downstream vendors** – One of the most critical tasks for indirect effects programs it to develop the requirements for line-replaceable units (LRUs). If the requirements are overly conservative, this results in unnecessary program costs if vendors do not have an off-the-shelf LRU capable of meeting the conservative requirement. If the requirements are too low, then a late-stage redesign during the certification phase could be necessary, delaying

certification and driving up program costs. EMA3D simulations can generate LRU interface control levels for lightning and HIRF with proven historical accuracy and EMC community acceptance.

2) **Reduce the number of development tests** – The use of EMA3D simulation tools reduces the need for testing to determine the interface transients and interference levels. Further, trade studies can be performed via simulation that would be prohibitively costly otherwise.
3) **Provide data for FAA designated engineering representatives (DERs)** – The DERs will need data to support their case to the FAA. By preparing a certification simulation with the proper fidelity and with material property measurement inputs, the DERs will have a stronger case. EMA3D simulation is routinely used by IEL DERs in recent years.
4) **Provide evidence of IEL and HIRF considerations for FAA Acceptance** – The FAA will want to know that IEL and HIRF considerations have been part of the design process from the beginning. By providing EMA3D simulation results from the both the design and the certification phases, the FAA can see that initial concerns have been identified and mitigated.
5) **Exploit synergies in the various EM environments** – Once a full aircraft model has been developed based on CAD drawings and discussions with the design team, it can be reused with minor modification/cost for analyzing:
    - Lightning indirect effects
    - HIRF
    - Lightning direct effects fuel system ignition prevention
    - Antenna design (especially for antennas embedded in CFRP structures)
    - P-static wick sizing and placement
6) **Exploit synergies among program phases** – Once a full aircraft model has been developed during the design phase, it can be reused with some modification in the certification phases.
7) **Reduce program risk** – By using simulation techniques to determine the lightning/HIRF interface transients/levels early in the design phase, the risk of having a late-certification phase issue with a proposed LRU device is lowered.
8) **Shorten schedule** – There is often a chicken-and-egg problem with completing a design to mitigate lightning/HIRF issues and having a testable prototype. By providing trade-study feedback to designers early in the design phase, this issue is mitigated. Further, the design team for structures and the LRU design/specification teams can now work in parallel since estimated control levels can be generated earlier in the program.