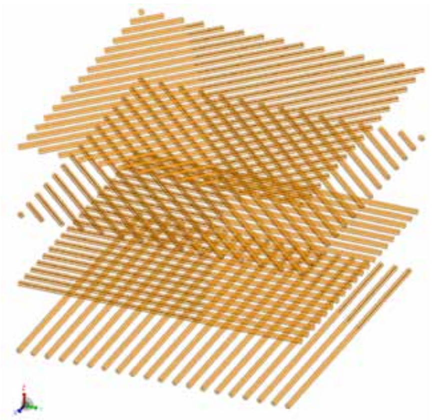
Application Sheet

FEKO

Comprehensive Electromagnetic Solutions

Electromagnetic Environmental Effects on Aircraft with Composite Materials

FEKO is well-suited for simulations involving anisotropic multi-layer carbon-fiber-reinforced composite materials.



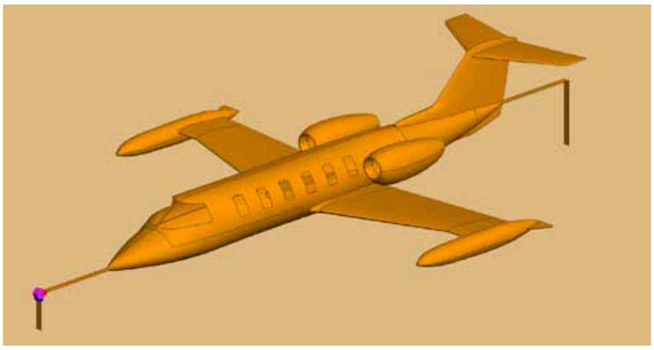
Carbon fiber arrangement in the composite material

Introduction

Carbon fiber reinforced composite (CFRC) materials are used often in the construction of small aircraft, since they offer sufficient mechanical strength while being lighter than metal. They are electrically conducting, but provide less shielding than metal and therefore electromagnetic environmental effects become a concern. This application sheet quantifies the effects for a couple of practical examples.

The first example involves lightning on a small jet and the second example shows high-intensity radiated fields (HIRF) on an unmanned aerial vehicle. In both cases, the quantity of interest will not simply be a field level inside the fuselage, but the currents or voltages encountered at the terminals of cable harnesses inside the fuselage. Those quantities are important since they are the interferences that may cause an electrical system to malfunction.

CFRC materials typically consist of several layers with the fibers of each layer aligned in different directions. The composite material used throughout this paper has four layers of 2 mm thickness each in which the fibers are rotated 0, 45, 90 and 135 deg. The conductivity is 1000 S/m along the fibers and 10 S/m perpendicular to the fibers. For simulations involving radio frequencies and microwaves, the resulting layer stack is modeled as a 2D sheet with an equivalent anisotropic surface impedance.



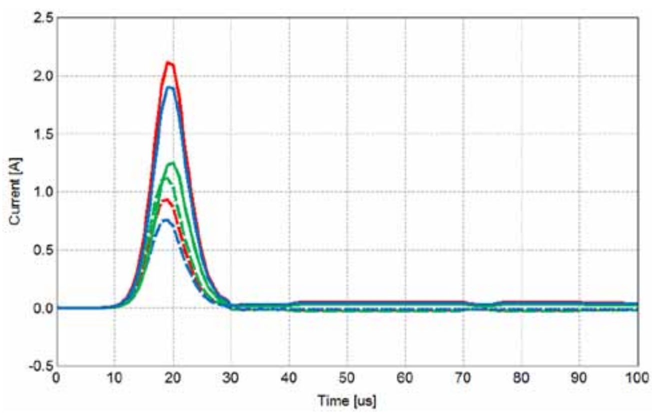
Aircraft model used in the lightning study

Lightning

The electromagnetic intereference caused by lightning striking a small jet was investigated. The test setup, similar to the way it would be done in a laboratory, is shown in the figure at the top right. In one case the entire aircraft (except for the windows) is made of metal; in the other case the fuselage is made of CRFC material. Electrical cables are present in the fuselage.

The lightning pulse was defined in accordance with IEC 62305 [1, 2]. It turns out that the interference at the cable terminals is caused by the early-time content in the lightning stroke, where the rate of change is high. For a fuselage made of metal and a fuselage made of CFRC material, the magnitudes of the interference are of the same order.

The coupling mechanisms, however, are different. In the case of the metal fuselage, interference can only enter through the windows.



The currents at three cable terminals caused by lightning stroke; metal fuselage (dotted lines) and CFRC fuselage (solid lines)

Without the windows, no interference occurs. The CFRC fuselage allows a significant fraction of the interference to enter through the material, which would still occur in the absence of windows.

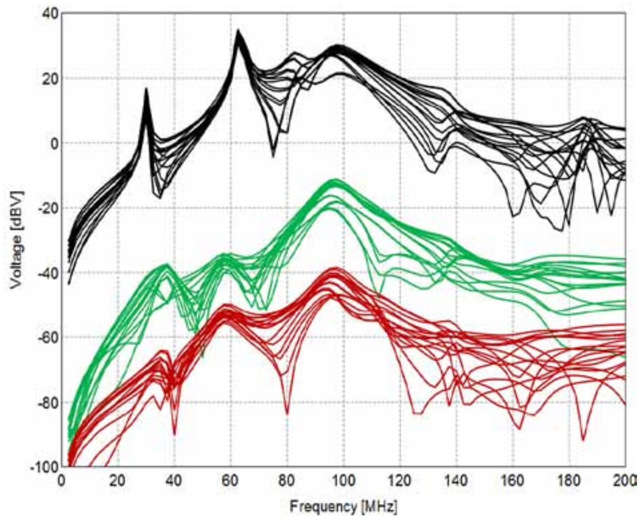
High-Intensity Radiated Fields

We have analysed the electromagnetic interference caused by HIRF [3, 4] incident on analysed unmanned aerial vehicles. Since they tend to fly at modest altitudes and modest speeds, HIRF from ground-based stations may hit them stronger and longer. This is especially a concern in combat zone, where they may be deliberately targeted with HIRF.

Figure to the right shows the wing span is 4.5 m and the length of the fuselage is 1.21 m. It has a glass dome with a camera near the front, and cable harnesses inside.

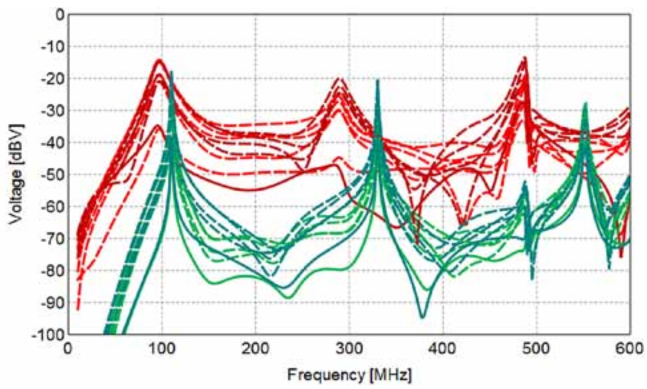
Generic drone used in the HIRF study

Simulations have been conducted for drones predominantly made of metal, CFRC material or plexiglass. Incident waves of 300 V/m were launched from many directions (one at a time) and at many frequencies. Figure to the right shows results for unshielded cables. Note that the glass dome is always present.



Typical voltages at the cable terminals for different fuselage materials. Black: plexiglass; green: CFRC material; red: metal.

Next, we investigate how braided cable shielding might reduce the interference. For the case of a fuselage made of CFRC material, see figure below, shows, for many angles of incidence, the HIRF-induced voltage delivered to the cable terminals for a range of frequencies. Note that, although a braided cable shield is beneficial at most frequencies, it does not dampen the resonances as much as might be hoped. The resonances shift and become narrower, as the signal conductors are now closer to their return paths, but their peak levels don't always fall by much. Fortunately, given that the CFRC shields better in the MHz range than in the kHz range, the induced voltage is not high at any of these frequencies.



HIRF-induced voltages at the terminals of the cables. Red: unshielded cable harness; green: shielded cable harness

Conclusions

Electromagnetic environmental effects on electrical cable harnesses in aircraft made with carbon-fiber reinforced composite materials can be studied successfully with FEKO.

In the case of lightning, the fields enter mostly through the CFRC material itself, not through the windows. Braided cable shielding can successfully reduce the induced currents in the cables.

In the case of high-intensity radiated fields, CFRC materials offer enough shielding, while the use of plexiglass leads to unacceptable interference levels. The induced currents can be reduced successfully by applying a thin metal coating on the fuselage. Applying a braided shield on the cable may not be adequate, as resonances related to the cable length are not always dampened much.

References

[1] IEC 62305-1, Protection against Lightning – Part 1: General Principles, IEC Standard, 2003.

[2] F. Heidler et al., "Parameters of Lightning Current given in IEC 62305 – Background, Experience and Outlook," 29th International Conference on Lightning Protection, Uppsala, Sweden, June 2008.

[3] Radio Technical Commission for Aeronautics, "Environmental Conditions and Test Procedures for Airborne Equipment," RTCA/DO-160C, December 1989.

[4] J.R. Elliot, "High Intensity Radiated Fields (HIRF) Risk Analysis," FAA Report DOT/FAA/AR-99-50, July 1999.