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SENSITIVITY CROSSTALK ANALYSIS STUDY FOR AERONAUTICS TEST CASE

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1. Introduction

With the advent of the "more electric aircraft", the number of electrical and electronic equipments on board aircraft and their associated connections and supplies has massively increased over the last 20 years. Indeed, there are no less than 500km of cable in an Airbus A380. In addition, to supply these equipments and to provide increasingly efficient services, new voltage supplies are emerging in aircraft, such as the HVDC (High Voltage Direct Current), the HVAC (High Voltage Alternative Current) or the PWM (Pulse Width Modulation). Moreover, the increased use of composite materials in the aircraft primary and secondary structures has a great impact on the electromagnetic environment of the electrical systems. In view of the certification, the equipments are all subject to standard test (e.g.: DO160 [1]), requiring that all electrical links should be protected from their environment and from each other, and limiting their emissions towards the environment.
The higher density of electrical cables, the diversity of signals transmitted, the new environment conditions and the test standards that have to be complied with make the EMC electrical design more and more complex.

The electrical links can be protected either by shielding, i.e. by placing a conductive screen that protects and limits the electromagnetic radiation and coupling, either by separating the links from the others with a certain distance in order to create a segregation between the signals and powers transmitted. The assembly in bundle or harness of cables transmitting similar signals is called a "route".
In the second case, it is essential to determine the installation distances between harnesses with different type of signals like power or data. The aim is to have the minimum crosstalk current compared to a less restrictive installation (to limit the size of the harnesses installation). However, it is important to determine which harness installation parameter is predominant for crosstalk.

2. Test case

The installation for two harnesses (one considered as the victim, the other as the aggressor) of different routes can be determined by analyzing several geometric parameters: the “height” (distance) of the harnesses with respect to the ground plane (h1 and h2), the distance between the two harnesses and the natural random positioning of the cables that we find within the victim harness. The random position of the cable in the harness is approximated by the rotation of the victim harness on itself offering a different surface facing the aggressor harness. Each parameter has to be set in order to have a given installation as shown in figure 1.

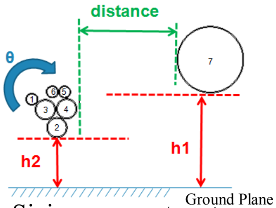

Figure 1. Sizing parameters for crosstalk

The test case consists in analyzing the sensitivity of the different parameters on the crosstalk between an aggressor harness and a victim harness. To be able to simulate an important amount of test cases, some approximations have been made. The first approximation concerns the taking into account of the positioning of the conductors with respect to each other by modifying the angle of the victim harness on itself and not moving only each conductors. The second approximation consists in describing the aggressor harness by a single equivalent conductor that remains valid for a common mode injection [2]. This single-core has a 10Ω load on one side and a 50Ω load on the other side. These charges are representative to the first order of what could be observed on aircraft. A generator of 1V is applied to the 10Ω load side. The third approximation is to consider the ground plane as infinite.
The victim harness consists of three cables that represent sensitive links commonly used on aircraft. The first is a single-wire cable with conductive core and insulation, which supplies a common-mode resistive load. The second is a two-wire cable, which supplies a differential resistive load, and the third is a three-wire cable, which supply a common mode capacitive load.

3. Tools

The modeling protocol consists in using the electromagnetic topology applied to the theory of transmission lines. The software tool chosen is CRIPTE [3], developed by ONERA. Its LAPLACE module computes inductance and capacitance matrices. These parameters are derived from the geometrical description of each conductor inside the bundle and their electrical features by solving the Laplace equation. The parameters necessary for these calculations are the coordinates of the cables ,the electrical reference and the permittivity of the insulators. From these matrices of the line parameters, it is possible to construct a topological network representing the power chain in the form of tubes connected and terminated by junctions. The end loads are placed in junctions and the line parameters are introduced in the tubes. This method provides the current and voltage values throughout the network, whether complex or simple, for a reasonable computation time from an industrial point of view. Thus, crosstalk studies can be used [2].
Generally, the size of these problems requires sophisticated and extremely expensive simulation codes in computing time. The use of simulators is therefore binding in the industrial field. It is therefore advisable to organize and choose for optimal or ideal simulations in order to obtain relevant results. This approach to understanding and synthesizing a process of any kind involves the realization of experiments: one speaks of an experimental plan. In general, this approach consists in carrying out a series of experiments that are necessarily feasible, independent from each other and determined a priori. This technique will seek to establish the links between two types of parameters: the response (physical magnitude studied) and the factors (physical variables that can be parameterized by the experimenter influencing fluctuations in response). Thus, among all the numerical experimental design methods developed in the literature, the complete factorial design is a sensitivity analysis technique that exhaustively combines all possible combinations of input variables with a finite number of parameters [4]. Here we consider four factors (h1, h2, distance and θ), each of which can take two values so 16 experiments.

4. Results

If we observe the current on the conductor 2, we can detail the primary effects for each factor over a wide frequency band as shown in Figure 2. Here we do not take into account the effects linked to the coupling of factors such as the combined evolution of h1 and h2 for example but just the influence of each factors on current derived from the crosstalk between the aggressor (conductor 7) on the victims (conductors 1-6).

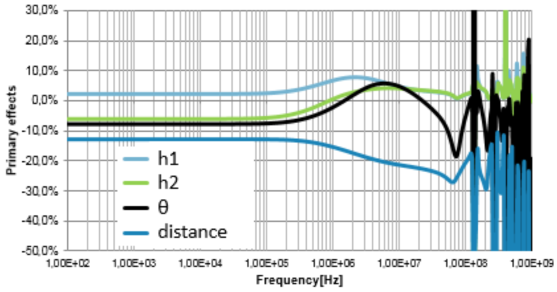

Figure 2. Primary effects for four factors

It will be noted here that the value of the distance between the harnesses seems to be the predominant value for 2 levels and 16 experiments.

5. Conclusion

In conclusion, this study shows that the distance between the harnesses is the most important parameter among the 4 factors studied. Nevertheless, an important limitation to this method can be pointed out. Indeed, by having only two minimum and maximum bounds, the tendency appears only for the passage from one to the other and we suppose that the variation is linear. It is possible that a maximum appears between these two extreme values, which could change the importance of the influence of the parameters. Moreover, it would be important to study the influence of the end loads. For this, it will be necessary to go through other methodologies that proved to be relevant for identifying extreme quantile or low levels of probability and their sensitivity to uncertain variables.

6. References

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