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THE CONTROL OF ELECTROMAGNETIC COMPATIBILITY IN MODERN HELICOPTERS

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THE CONTROL OF ELECTROMAGNETIC COMPATIBILITY IN MODERN HELICOPTERS

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ABSTRACT

The problem of Electromagnetic Compatibility (EMC) in modern helicopters is becoming more and more important due to the installation of complex integrated avionic systems and the use of advanced composite materials which impair and reduce the electrical conductivity of structures. In order to avoid unwanted interference effects, which could only be solved by means of flight limitations and the acceptance of performance degradations, it is imperative to take into account the EMC requirements and to start a sound program of EMC control at an early stage of the project.
The EMC activity should be addressed to the following main areas:

- mechanical design;
- electrical design;
- electronic/electrical equipment engineering;
- EMC testing.

The overall EMC activity is carried out by means of two main tools:

- mathematical models: suitable computer codes which predict possible interference situations and critical areas;
- EMC instrumentation: it is essential to have the complete set of measuring equipments foreseen by current EMC specifications and well trained personnel.

1. INTRODUCTION

In order to avoid unwanted interference effects which could be solved by means of flight limitations and the acceptance of performance degradations it is essential to take into account the EMC requirements and to start the EMC control program at the early stage of the project. Two types of EMC problems may arise:

- internal EMC : the equipment in the aircraft shall not interfere with itself;
- external EMC : the equipment in the aircraft shall not be interfered by the external environment which may be either the usual operative ambient or the environment which represents extreme situations of hazard such as those related to lightning and nuclear effects.

The EMC activity shall be addressed to the following main areas of interest:

- mechanical design : the control of structural design and mechanical installation of equipment in order to achieve low values of bonding resistances and impedances;
- electrical design : the control of the power distribution systems, wire routing, antenna separation in order to achieve a high degree of electrical isolation between interference sources and susceptibility receptors;
- electronic/electrical equipment engineering: the liason with the suppliers of helicopter equipment/subsystem in order to monitor the EMC activity in both design and testing;

- EMC testing : the study and development of suitable test methods capable of demonstrating the required EMC safety margin during system level tests.

2. MECHANICAL AND ELECTRICAL DESIGN

The correct installation of the equipment within the aircraft fuselage with the aim of achieving low bonding resistances and high shielding effectiveness values is already a result of outstanding importance, which can be achieved by means of a continuous control and monitoring of the mechanical installation and design.
This aspect of the EMC activity has become of particular importance now that there is an increasing use of composite materials, which entail problems related to lightning protection, EMC and EMP hardening.
The aircraft structure shall be designed so as to be electrically as leak-proof as possible in order to obtain good shielding effectiveness and low voltage drops. These objectives can be achieved by metallizing the CFC structural parts and by selecting proper methods of panel jointing.
The electrical design is obviously the most important tool which is in the hands of EMC engineers to control the overall compatibility of the system.
The following main points shall be taken into account in the electrical design:

- Grounding. The overall grounding philosophy shall be clearly established and understood. The Single Point Grounding (SPG) system represents the most reliable and correct method of grounding. This solution is obviously not always applicable in all cases (for example in the case of RF equipment); therefore it is essential to grant concessions where it is necessary but with the clear understanding of implications and consequences.

- Bonding. Electrical continuity at DC and RF shall be achieved at any point both along the structure and between primary and secondary structure.
Low bonding resistances mean low common mode noise for equipment grounded on the structure, high values of shielding effectiveness.

- Wire routing. Cables shall be divided into classes of susceptibility and emission and physically separated accordingly. The cable separation represents one of the most valid methods of EMI reduction; obviously this technique shall be applied within the constraints of weight limitation and space availability.

- Shielding. Shielding of cables and compartments could help in reducing electromagnetic coupling effects, but again this possibility shall be adopted within the frame of all those constraints which have been previously indicated.

- Space and time separation. Space and time separation generally speaking should solve any problem if there were no limits in the use of these techniques.
But unfortunately antennas and equipment are so closely installed that there are few chances of solving EMC problems in this manner; time blanking techniques can be used for those equipment which do not lose information or are not affected in their modes of operations if interrupted frequently.

- Frequency separation. This technique of EMI reduction shall be adopted whenever it is possible. The extensive use of EMC systems and in general broadband equipment renders frequency separation impractical mainly due to operational constraints.

- Filtering. The techniques of reducing EMI in frequency domain by means of filters and in time domain by means of suppressors and limiters should only be used at equipment level because are not cost effective and reliable at system level especially in aircraft applications.

The electrical design is carried out by means of suitable mathematical models. The major system level analysis model is the Electromagnetic Compatibility Analysis Program (IEMCAP).
IEMCAP provides detailed models of the system elements and the various mechanisms of electromagnetic transfer. It performs the following tasks:

- provide a data base which can be continuously maintained and updated;

- evaluate the impact of granting concessions;

- assess the effect of design changes on system EMC;

- survey the system for incompatibilities.

The coupling models within IEMCAP are:

- wire to wire (within a bundle)

- antenna to antenna

- antenna (or field) to wire coupling through an aperture

- box to box (within the same compartment)

- field to antenna

- field to box

One of the major limitations of IEMCAP seems to be the size of the system that IEMCAP can analyze per computer size run.
This difficulty can be overcome by an intelligent use of the program: for example the equipments per run limitation can be solved by multiple runs based on system ports and coupling modes. Another limitation may be the large amount of input data which may not always be available especially if the aircraft is to be built. The approach, that can be used, can be described in the following main steps:

- The structure is described and all antenna to antenna coupling modes are analyzed along with the external environment to antenna coupling mode;

- Antenna and external field to wire coupling mode is examined for all those wires connected to susceptible ports that pass near apertures;

- The total wiring of the system is partitioned into subsets according to some assumptions: critical ports, emission spectra, wire lengths, wire types, loads, susceptibility. Those wires which are unique within each subset are grouped together into a ficticious bundle with ficticious boxes. The wire to wire coupling and the internal field to wire models are run. The results of this simulation may provide useful information to help design wire bundles.
  Another possibility could consist in the study of different wire routings after assuming the box location.

- Box to box coupling can be studied by grouping boxes together.

An outstanding feature of IEMCAP is the tight relationship with EMC specification test methods. The unrequired emission and susceptibility spectra are based upon MIL-STD-461A or MIL-E-6181D. Deviations from these specifications can be imposed or examined.

3. EQUIPMENT ENGINEERING

All equipment/subsystems which are to be installed on the aircraft shall be designed and tested according to the applicable EMC specifications. In case of GFE equipments the relevant test results shall be evaluated to establish whether the equipment/subsystems can be accepted as they are or system changes shall be applied to solve some peculiar problems. This activity which is generally known as EMC equipment engineering is mainly addressed to monitor the EMC design and testing, to evaluate test results, to examine design changes and concession requests.
The EMC equipment engineer shall remain in tight contact with the supplier to monitor all the EMC activity which shall be described in the following documents:

- EMC Control Plan: it gives a detailed description of the approach undertaken by the supplier to avoid EMC problems with particular reference to electrical design, mechanical design, circuit and wiring lay out, waveform selection, internal wiring separation, filter and suppressor selection. In addition the supplier shall give all the data necessary for a suitable computer code.

- EMC Test Plan: it describes the applicable test methods with all those details which make someone else capable to repeat the tests if necessary. The test set ups are shown with the full description of all details related to the equipments under test. In particular the modes of operation of the equipment and the susceptibility criteria shall be given. The actual lay out of the equipment under test and the connections with its test equipment are shown. It is important to notice that all precautions shall be taken to avoid the test equipment influences the EMC measurement in any manner; this can be obtained, for example, locating the test equipment outside the EMC chamber and decoupling the connection between the test equipment and the unit under test by means of fiber optic links.

- EMC Test Report: it presents the test results pointing out the deviations from the applicable specifications. It is quite important that in the test report all those details which give confidence that tests are correctly performed are given: the ambient noise levels both for conduced and radiated emission, the recognition criteria of the type of emission (narrowband or broadband), the criteria of identification of wanted signals in the test on signal lines.
  The cases of noncompliances shall be examined in detail to find out the sources of emissions or susceptibilities and corrective actions shall be indicated. It is the task of the EMC equipment engineer to evaluate the concession by a correct trade off between the advantages and benefits of rejecting the concession and the implications of accepting it with obvious impacts on system performances.

4. EMC SYSTEM TESTING

Simple qualitative checks and functional tests are no longer sufficient to clear complex systems: there is a well defined need of achieving a quantitative level of safety before equipment malfunction occurs. Much talk is going on within the EMC community about the definition of system tests leading to the establishment of adequate safety margins. EMC system tests are carried out with cause-effect technique: the equipment under test is monitored while the other equipments of the system are operated in sequence as interference generators.

Experimental evidence shows that interference effects are not always repetitive and in many cases malfunctions change randomly around an average level. In order to take into account the possible variations between systems and equipments during production and allow for changes of their characteristics due to age effects it is quite important to perform EMC measurements with a safety margin which establishes the degree of confidence in the compatibility level of the overall system.
MIL-E-6051D establishes that a safety margin shall be considered for those subsystems/equipments assigned to category I and II:

- Category I - EMC problems that could result in loss of life, loss of vehicle, mission abort, costly delays in launches or unacceptable reduction of system effectiveness.

- Category II - EMC problems that could result in injury, damage to vehicle or reduction in system effectiveness that would endanger success of mission.

In case a safety margin is considered essential it is stated that system performance requirements, error budgets, tolerances, repeatability and instrumentation requirements shall be taken into account. The safety margin can be specified by establishing the following thresholds:

- Performance Threshold: it represents the boundary of successful or unsuccessful achievement of a Technical Performance Characteristic (e.g. the S/N ratio of the Intercom System must be 40 dB). The Performance Threshold is usually defined as that signal at particular interface point measured when the system is operating in a quiet environment representing the baseline of the EMC measurements (the minimum number of equipment are operating at the less emissive conditions).

- EMC Threshold: it represents the level of undersired radiated or conducted signals which do not affect the Performance Threshold of the equipment under test. The EMC Threshold is generally determined in two manners:

  a) by measuring the interference at the input terminal of the equipment installed in the system during the activation of the other emissive sources;

  b) by making reference to the level of susceptibility signals measured during laboratory EMC tests.

  It is important to stress that this type of Threshold is tightly related to the equipment performance and may be considered as an indirect method of measuring the Performance Threshold.
  The safety margin is defined as the difference between the relevant threshold and the actual value of the unwanted signal; one can specify a Performance Safety Margin (PSM) and an EMC Safety Margin (EMS).
  The correct measurement of the PSM is carried out by rendering the system under test more susceptible to interference with the artificial variation of its Performance Threshold by the wanted safety margin (e.g. the S/N ratio of the Intercom System is increased to 46 dB). Unfortunately this is difficult and in any cases impossible because it would be necessary to carry out the measurement of the electrical signal within the unit examination or to use a properly designed simulator. Another approach could consist in increasing the EMC Threshold. In practice the test is performed by measuring the maximum interference signals at critical interface points when the interference generators are operated and then reinjecting the same signals but increased of the desired safety margin. If the system performance is not degraded the ESM has been demonstrated.

Unfortunately this type of measurement has many limitations and difficulties:

- the Performance Threshold and its tolerance shall be evaluate quantitatively in any case;

- if the measured EMI signal is broadband, or random, it cannot easily be generated with an external signal source and in addition it is difficult to establish where the safety margin shall be applied (to the modulation, frequency occupancy, repetition rate, amplitude and so on);

- when the interface point is well shielded the level of required power to be reinjected may be prohibitive;

- during reinjection (galvanically coupled) the situation may become critical because coupling networks of low impedance shall be used. Sensitive circuits may be degraded just by connecting the coupling network to its test point;

- the measurement of coupled interference points is done by means of high impedance probes with an obvious frequency limitation.

A third approach to the safety margin tests is possible by making reference to susceptibility laboratory tests (in particular CS01, CS02, CS06 and RS03 of MIL-STD-461/462/463).
The system test is carried out by measuring conducted interference at critical interfaces and radiated interference at the location of the equipment under observation during the activation of emissive equipments; these values are compared with the ones measured during susceptibility tests and the safety margin is established. The validity of this comparison is correct as long as there is similarity between the test methods in the system and in the EMC laboratory.

Also in this case there are some limitations and difficulties:

- the test set up and the environment are different because the shielded chamber where the equipment is tested does not reproduce the ambient of the system;

- the cables are not representative of the system wiring;

- the test set to operate equipment does not represent the actual (both electrical and mechanical) load of the equipment.

On the other hand this method of measuring the safety margin is advantageous because does not require special instrumented equipments, is not limited in frequency and uses the vast amount of laboratory test results.

5. CONCLUSIONS

The success of an EMC program is related to the joint effort of many engineers involved in different technical branches of the firm because the EMC activity, by definition is an interdisciplinary activity.
In our opinion the key points of the EMC program are the prediction methods and the testing activity: they provide the only technically sound and correct approach.

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Giuseppe Meschi was born in Merate on the 21st March 1948. He received the degree in electrical engineering from the Politechnic of Milan in 1972. He joined Agusta in 1974 where he has been working in the avionic field with main interest in integration of communication and navigation systems. Presently he has been encharged of EMC and antennas design and testing for all Agusta programs.