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The Role of Electromagnetic Compatibility Qualification Considerations in Airborne System Integration Programs

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Abstract

There are many misconceptions that surround Equipment Electromagnetic Compatibility (EMC) qualification testing and installation assessment. The objective of this paper is to raise awareness of some of the issues that applicable to the subject, and offer a perspective of what qualification means to a certification program both technically and programmatically. The paper seeks to analyze common situations that occur during system integration programs and provides an indication of the level of detail to be considered in EMC design assessments. For the purposes of this paper the term EMC is considered to cover all aspects of electromagnetic compatibility, including, High Intensity Radiated Fields (HIRF), Indirect Effects of Lightning (IEL) and Electromagnetic Pulse (EMP).

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1. Introduction

It may be considered an axiom that aircraft programs the world over will use at least some equipment or systems that have been previously developed and qualified to meet the requirements of a previous program. This equipment may be Commercial Off-The-Shelf (COTS), which may or may not have a Technical Standard Order (TSO), or be some modified version of already existing equipment for which qualification similarity may be claimed. Use of such equipment may bring many commercial benefits to the program however caution should be exercised when

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reviewing its actual qualification standard, which may not be completely compatible with the new program requirements. Taking a statement of qualification at face value is fraught with risk and should not be considered as a guarantee that the equipment will meet the new program requirements or be certifiable on the project aircraft without additional unforeseen work. Thus it is essential to have a thorough view of the equipment itself, qualification methods, test results, installation designs, platform characteristics, intended operational use and the new program's requirements. Understanding all the above information will not only assist to determine the proper equipment for the program, but also contribute to the system integration processes. As an EMC engineer entering into the aircraft design industry, it is very difficult to do the in-depth analysis without years of work experiences. The paper aims to explain some common EMC considerations that occur during system integration programs, give the uninitiated person a guideline to perform this work. The paper mainly adopts analysis methods and taking samples to illustrate the aspects need to be considered and how to weight during the analysis process. Seven aspects of common EMC considerations are presented within the scope. The paper follows these seven aspects and comes to the conclusion finally.

2. The equipment has been qualified on a previous program

This is a common situation and one where the uninitiated person can easily be misled. The Electromagnetic (EM) performance for both emissions and susceptibility may be highly dependent on the design and construction of its power supply and interface wiring, particularly in that part of the spectrum where cable coupling dominates the ingress and emission of Radio Frequency (RF) energy, being generally accepted as frequencies up to around 400MHz.

It should never be assumed that the wiring configuration used during qualification is necessarily representative of the installation on the new project (or even representative of the original project installation for that matter). Qualification test programs often require many compromises, some which may affect the qualification outcome. Many manufactures provide installation manuals for their equipment, which define the required installation design reflecting that with which the equipment was qualified. Failure to follow these installation criteria effectively removes the "qualified" status for that equipment andinvalidates any assurance of electromagnetic performance.Some other factors that may influence the apparent EMC performance include,

- Operating mode of the Equipment Under Test (EUT) which may be dependent in many cases on simulation and stimulation of the various interfaces;
- The electrical bonding of the EUT;
- Variations in test techniques and measurement procedures, even standards such as DO160[1] in some cases offer sufficient latitude for manufacturer instructions to redefine test techniques that may significantly affect the results obtained.

3. The equipment has been qualified to a different standard

Most standards are continuously updated which can introduce or delete test conditions, change test methods and significantly alter test limits. Sometimes additional test limits are introduced to cater for particular types of equipment or platforms however it is reasonable to generalize that the most stringent limits of any particular test condition has become more stringent as standards have evolved over time.Additionally it is common for the large airframe manufactures to produce their own test standard documents, which may be based on industry standard documents but with some variations. Similar to other existing aircraft manufactures, Commercial Aircraft Corporation of China, Ltd. (COMAC) is developing its own EMC standard documents based around DO 160. A common misconception is that there is a relationship between emission and susceptibility limits in a particular standard, this is generally not the case. As an example consider Mil-Std-461[2] test RS103 that specifies the electric fields equipment must tolerate. Emission requirements over the same band of frequencies specified in RE102 are many orders of magnitude less than the test limits of RS103. If the interference path was solely between cable coupling then some margin between the emission and susceptibility levels may be inferred, however the situation is far more complex. In the first instance the susceptibility levels are also intended to account for external non-platform

based influences such as HIRF as well as platform located transmitters. The fields generated by these sources are orders of magnitude higher than those typically found radiating off cables. Secondly the RE102 testlimits are intended primarily to minimize coupling to antennae and associated sensitive receivers, which will respond to signal levels many orders of magnitude lower than the RS103 levels. Thus any inferred margin between the emission and susceptibility test levels is invalid. When, as is often the case, equipment qualified to different test standards is integrated on a common platform there may be concern over the erosion of actual margins attributed to the combination of qualification standards. This may be the case when for example comparing absolute rather than relative susceptibility or emission test levels.

4. Equipment qualification compliance waivers

Sometimes equipment is supplied either with existing deviations or waivers granted or with an application for a requirement waiver on the new program. One of the most often cited quotes when faced with qualification non-compliance is that the manufacturers state that they “have installed this on many platforms with no reported problems”. This universal statement may mask the real situation which could be:

- The platform testing performed did not detect any EMC issues. Selective frequency interference problems being typically almost undetectable;
- The statement provides no comparative reference to the installation designs, the sensitivity of other equipment sharing the platform or the EM environment in which the platforms are operating;
- Is there in fact a mechanism by which an occurring in-service EMC problems can be reported and detail relayed from the operators to a cognizant engineer? Cases have occurred when interference problems, common knowledge to operational crews has either been accepted as normal or, if reported, detail fails to filter back to the engineers responsible for the equipment design and integration;
- Interference problems are often blamed on the “other equipment”, rather than the suppliers own equipment, i.e if the suppliers’ equipment is a source of interference then the victim equipment is perceived to be too sensitive. In the case of the suppliers’ equipment being susceptible, then the environment generated by the other source equipment is considered too noisy! Great care should be taken when accepting non-compliances, as a minimum the original test configuration should be understood and an analysis performed on how representative it is of the of the new installation.

Additionally the type of platform and operational environment of the platform(s) previously equipped should be reviewed wherever possible. Be prepared however for security and intellectual property restrictions or interested parties allowing only selective availability of meaningful data to severely limit any benefit from this approach. The source of any data obtained should always be considered, particularly if supplied by a party with a vested interest in the outcome.

5. Similarity to existing certified equipment

Very often the equipment to be installed on the new program will be different in some way to that which has been previously qualified. In the interests of cost and expediency manufacturers and programs understandably wish to re-use any qualification effort expended as far as possible. It is essential to ensure that the similarity being claimed is reasonable and appropriate to the program in question. Every situation is unique however some consideration guidelines may be established to assist in making this determination.

5.1. Component design category changes

- Is the unit enclosure the same method ofconstruction with the same apertures,aperture shielding?
- Are the internal compartments the same andhas the original clean/dirty segregationbeen followed?
- Are the same clocks, processors andinternal data busses utilized?

- Also consider the choice of clockfrequencies and their harmonics with respect to onboard receiver channel coherence;
- Has component technology changed, i.e. Transistor Transistor Logic (TTL), Field Effect Transistor (FET), and Complementary Metal Oxide Semiconductor (CMOS) etc.?
- Are new Printed Circuit Board (PCB) layouts incorporated?
- Has I/O or internal filter componentschanged?
- Is the same power supply module utilized?
- Has the power supply loading changedsignificantly?
- Have the external connector types changedand if so can the same interface wiring shielding and shield termination policy be maintained?
- Is equipment RF bonding and Safety grounding provisions the same?

5.2. Functionality changes

- Has additional functionality been added to the equipment that utilizes different types of circuits to that previously used?
- Have additional operating modes be added?
- Are there additional interfaces to the equipment and if so are these more of the same type as previously existed or new types?
- Have channel bandwidths been maintained?
- Has the software/firmware changed, in particular the Error Checking, Reset/Recovery, Watchdog features and method of implementation?

5.3. Qualification fidelity considerations

- Does the equipment perform any safety critical or essential functions?
- Has any “engineering” EMC testing been performed to support a claim of similarity?
- Did the original qualification fully evaluate any latent or redundant functionality in the design?
- Is the comparison being performed directly between the desired unit and the original qualified unit or is qualification claimed via intermediate variations of the original units for which qualification similarity has already been exercised?
- Consider the effect of aggregation of a number of individually small changes;
- Are there additional requirements such as EMP, or IEL?
- Do the project requirements require more stringent test limits than previously applied?
- Did the original qualification exhibit significant margins to the specified requirements?
- Is there reason to doubt the quality of the original qualification data?
- Consider the protection afforded by the airframe installation to the equipment and its interface wiring as well as its proximity to intentional transmitting sources and sensitive receiving equipment;
- Is there a history of EMC problems with similar equipment?

The supplier should always be required to supply a formal statement of similarity that details the changes and rationale for the similarity claimed and includes any supporting evidence necessary to substantiate the claim.

6. No qualification data is available for this equipment

Inaccessible qualification data may be due to a number of reasons such as:

- The equipment was originally qualified along time ago to early drafts of test standards that did not contain some of the modern test requirements;
- The equipment design is simple and such that EM performance can be predicted analytically;
- Provision of qualification data was not included in the program contract;

- Security or proprietary information constraints.

Depending on the functional criticality of the equipment and/or its complexity it may be necessary to insist on a new qualification program as a means of supplying test data. Sometimes platform level testing may be substituted, however this usually represents a significant technical and program risk and should be considered only as a last resort. A practical option may be to seek an alternative part that is supported with qualification data.

7. Equipment qualified in different configurations

A primary objective of qualification testing required by the military and civil standards is to test the equipment in a configuration that is representative of the aircraft installation. A situation may occur because of different installation criteria, an example being a system qualified with high quality standard shielding and later installed with simplified shield configurations. In such as case particularly if the system has some critical or essential functionality it may be necessary to re-qualify the system, at least partially in the appropriate configuration. Another situation that is becoming more common is where the integrator or qualifier insists upon deviations from the established test methods. A common example is the practice of removing cable shields during RF Susceptibility and Lightning tests. There are a number of issues with this such as:

- The wire configuration is no longerrepresentative of the aircraft installation;
- Simply removing the shield does not simply result in a standard "X dB" of susceptibilityincrease, the primary current path can change and so to may the primary frequencies of susceptibility. Any remaining semblance to actual installed EM performance is at best difficult to justify;
- Often the shields are not removed as they should be but just disconnected, which can introduce capacitive effects and produce different susceptibility performance again.

Only in very exceptional circumstances and then only for clearly stated and understood rationale should practices be implemented that take the qualified system configuration away from that representing the installed configuration. When this occurs it should be clearly stated in thequalification reports that the qualification wiring configuration was not as per aircraft installation requirements. The integrator is responsible for verifying the actual qualification test configuration for each test condition represents the installation requirements for the current project.

8. Qualification based on in-service performance

Occasionally a supplier may attempt to rationalize non-compliance with some aspect of qualification by claiming that the system hasbeen in service for "X" number of years on "Y" number of platforms without problem. Airworthiness Authorities as an example usually have a clear policy that this has no bearing on the project certification. For instance when considering similarity between differing platforms and system installations designs the SAE 5415A[3] provides a good level of guidance on what may be considered acceptable for assessment of IEL however the same criteria applies equally well to other aspects of EMC certification. These are summarized as follows:

Table 1.Similarity consideration

Condition	Generally Acceptable Similarity Criteria	,Generally Not Considered Similar
Aircraft Type	-Asimple Stretch of an airframe -Aerodynamic improvements	-General aviation to transport category -2 engine narrow body to 4 engine wide body
Equipment Location	-Going from an unprotected (external) to a protected area (inside pressure cabin)	-Going form a protected to an unprotected area
	-Moving away from an aperture	-Moving to a location near an aperture
Airframe Construction	-Same material	-Different material such as from

		Aluminum to Composite
Apertures	-Deleting a door/window or equivalent apertures -Decreasing the largest dimension of equivalent aperture	-Addition of large cargo bay door or other aperture -Increasing the largest dimension of an aperture
System Interfaces	-Adding a small number of circuits of the same type as existing circuits	-Changing from Analogue to Digital or vice-versa -Changing from wire to optical fibers or vice-versa
Wire Size and Routing	-Comparable exposure of wiring -Wire routes moving from less protected to more protected area	-Changing from wire to optical fibers or vice-versa -Wire runs changing from protected to less protected area
Connectors	-Going from pigtail shields to properly terminated at a backshell -Shortening a pigtail -Going from smaller connector to larger connector providing the wire bundle does not change	-Going from properly terminated backshell shields to pigtails -Going from shielded to unshielded wiring -Installing lower performance shield
Cable Bundle shielding and Wire Type	-Going from untwisted wires to twisted -Going from unshielded to properly terminated shields -Installing Higher performance shield	-Going from twisted wires to untwisted -Going from shielded to unshielded -Installing lower performance shield
Antenna	-Direct replacement of an antenna with one of similar performance -Removal of antenna	-Relocation of existing antennae -Addition of new antenna -Change of antenna characteristics
Grounding	-Using dedicated ground returns	-Not using dedicated ground returns
Bonding	-Any change must be reviewed, assume it is not acceptable until proven otherwise	
System Modification, Hardware, Software, Firmware	-Any change must be reviewed, assume it is not acceptable until proven otherwise	

9. Conclusion

It is evident that system integration using existing or modified equipment not a straight forward exercise for the EMC engineer. There is much detail that must be considered if safe and interference free operation is to be assured, even relatively innocuous details can have a significant effect on a systems installed EMC performance. It is necessary to obtain an in depth view of qualification methods, test results, equipment and installation designs, platform characteristics and intended operational use to be able to provide an EMC assessment with a justifiable degree of confidence.

References

[1] RTCA DO160G, Environmental Conditions and Test Procedures for Airborne Equipment.
[2] MIL-STD-461F, Requirements for the control of electromagnetic interference characteristics of subsystems and equipment.
[3] SAE ARP 5415A, Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning.