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Risk Based EMC for Complex Systems

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Abstract

The rule-based approach, i.e. following electromagnetic interference standards, is the basic methodology assumed to result in electromagnetic compatible systems operating properly in their intended environment. For complex systems we need a smarter approach, based on assessing and controlling the electromagnetic risks. This risk-based approach is described, and applied to naval ships.

1. Introduction

The introduction of the European Directive for Electro-Magnetic Compatibility (EMC) in 1989 [1] resulted in a new era where nearly all equipment, even military [2], had to comply with the essential requirements of the Directive. The common approach in the civil domain is to follow the harmonized EN and/or IEC standards and follow the 'presumption of conformity'. This resulted in the widespread (wrong) belief that compliance with a standard = compliance with the Directive. In the military domain EMC is achieved via managing, and controlling, the risk of interference. This has been described in MIL-HDBK 237, Def-Stan 59-411 and VG 95370 [3, 4, 5], among other good documents, about management of complex systems. This is 'EMC Engineering'. The use of a Electro-Magnetic Interference (EMI) standard is not the goal, but a way to achieve EMC. It is particularly valid for complex systems. In this summary paper the reasons for using the risk-based approach are described from the legal perspective and the cost perspective.

2. Risk based EMC from legal perspective

The risk-based approach is used in several domains, for instance safety, while the rule-based approach is the conventional approach in (civil) EMC. But recently we observe the risk-based approach also in the EMC domain. One of them is the Lloyd's which included the risk-based approach as an alternative to the conventional rule-based approach in their Naval Rules and Regulations for the classification of naval ships [6].
The risk-based approach is also become more visible in the newest European Directives, including the EMC Directive. In the 'Blue Guide' Directives [7] it is written:
Harmonised standards never replace legally binding essential requirements. A specification given in a harmonized standard is not an alternative to a relevant essential or other legal requirement but only a possible technical means to comply with it. In risk related harmonisation legislation this means in particular that a manufacturer always, even when using harmonised standards, remains fully responsible for assessing all the risks of his product in order to determine which essential (or other) requirements are applicable. After this assessment a manufacturer may then choose to apply specifications given in harmonised standards to implement 'risk reduction measures' which are specified by harmonised standards.
When designing complex system it is impossible to apply a harmonized standard, because there is no standard which fits such a complex system. In other words, the EU requires that a risk based approach is followed for complex systems. How it is performed will be described in Section 4.

3. Risk based EMC from cost perspective

The costs for naval ships are escalating at an unsustainable rate [8] as shown in Figure 1. The data in this figure shows the cost development of surface combatants of the US Navy between 1950 and 1999. The cost of the recently put-into-service Zumwalt Class DDG1000, is more than 4 B$ [9] which is in line with the logarithmic price development between 1950 and 1999, extrapolated until 2016.

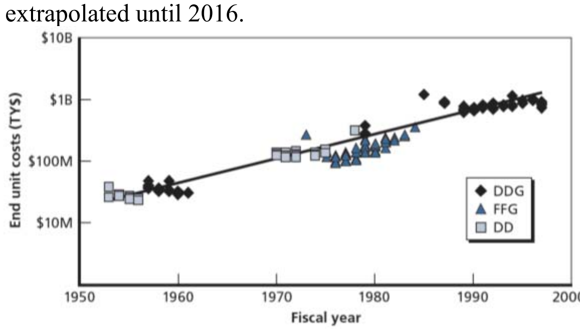

Figure 1. from [8]: Cost Escalation for selected surface combatants according. DDG: Guided missile destroyer, FFG: Guided missile frigate, DD: Destroyer.

Several factors contribute to this rapid increase in procurement costs of ships, but according [8], 3 of them out of the top 10 of cost-drivers are EMC standards being:
• MIL-STD-461E Electromagnetic Interference [10],
• MIL-STD 464A Electromagnetic Environmental Effects (E3) Requirements for Systems [11],
• MIL-STD-469B Radar Engineering Interface Requirements, Electromagnetic Compatibility – Frequency Spectrum Guide for Radar [12].
The basic approach is to implement the applicable standards without any further consideration, i.e. rule-based. For naval ships this could be aforementioned MIL-STD 461E (now –G [10]) As equipment fulfilling these standards completely is either difficult to acquire, or costly, the only perspective is to 'harden' (Commercial) Off The Shelf (COTS) equipment. This hardening has its costs, as shown in the report of the Defense Science Board Task Board on Integrating Commercial Systems into the DOD, Effectively and Efficiently [13]; It appears that hardening results in an increase of cost of a (relatively simple) naval ship from $220 million to $500 million.
Instead of following the rule-based approach, a risk-based approach for naval ships was developed and implemented by several companies, knowledge institutes and the government. They decided to tackle the challenge of high EMC related costs on board Naval Vessels together, resulting in the consortium "EMC for Future Ships" which incorporated:
• a navy (Royal Netherlands Navy),
• a Classification Society (Lloyd's Register of Shipping),
• a shipbuilder (Damen Shipyards),
• a combined Combat-System-Integrator (CSI) and equipment manufacturer (THALES Nederland),
• a combined E-System-Integrator (ESI), installer as well as an equipment manufacturer (RH Marine Netherlands) and
• a university (University of Twente).
One of the major results is that the Lloyd's Register Naval Rules were adapted per January 2017 [6] enabling the rule-based approach.

3. Implementation of Risk based EMC

The risk-based approach is nothing more than proper EMC engineering, and comparable to the Risk Inventory and Evaluation (RIE) methodologies applied in other domains. With the modification (Volume 2, Part 1, Chapter 3, Section 3.3 and Section 4.13. of the Lloyd's Register Naval Rules [6]) the risk based EMI approach is also allowed for naval vessels. This gives the possibility to focus less on emission and immunity levels on which the standards are based and more on interruption of / attenuation by the coupling path. As a consequence this allows ship builders to apply COTS equipment from which the ElectroMagnetic (EM) quality is nowadays much better than ever before without any additional measures, or costs.

The risk based EMC approach for naval ships involves the following four elements:
1. EMC management plan
2. EMC control plan
3. EMC implementation plan
4. EMC validation and verification plan

For development of for instance a radar system, more elements are needed, including an analysis of the EM environment, and detailed analysis of the radar front-end. The same applies to other complex systems. The description of how the risk-based EMC approach is performed for naval platform is just an example of the process.

5.1. EMC management plan

The EMC management plan has three important objectives. The first one is to define the ElectroMagnetic Environment (EME) in which the ship will operate. In other words what does the customer want with his ship and what kind of EM threats follow from these requirements. The second objective is to fix the requirements, from a legal perspective but also from the customer's perspective, for example:
• The use of mobile radios (walkie-talkies) on board introduces a disturbance source which can create significant field strengths at any location on board, possibly causing interference.
• Radio communication equipment to be installed
The objective goal is to define and agree on the responsibilities between all parties involved: contractor, sub-contractors, and suppliers. If all contractors, sub-contractors, system- and equipment suppliers, and component manufacturers take all necessary steps that whatever purchased parts they use, their delivery is completely suited to be used in a maritime environment, the ship will be too expensive. If none of these parties take these steps, there is a high risk on interference resulting in malfunctions. The challenge is to make sure that the party that can prevent EMI in a naval environment, against the lowest overall costs, will do so. Since cooperation between all partners is important to reach EMC and a reliable ship at the lowest costs, it is important to facilitate this cooperation for example by means of an EMC team.
The kind of inspection, verification and validation is required to convince classification society and customer of the reliability of the delivered installation should be described also. Inspection, verification and validation can be real cost drivers so all involved parties should roughly know what is expected from them if they make their offer.
To summarize the management plan defines the EM threats that follow from the requirements of the customer and states who is responsible for what.

5.2. EMC control plan

The EMC control plan is all about controlling the identified risks and defining measures. These include best practices to mitigate those risks, and translating them into purchase specifications for sub-contractors and system- / equipment suppliers. The input of the EMC control plan consists of the EM threats and operational requirements from the customer combined with the equipment that will be used on board. An easy tool to identify risks is a "source victim matrix". In a source victim matrix interference risks are identified and mitigated with best practices [15, 16]. Based on the risk analysis the output of the control plan will be a number of documents and instructions which enables the system integrator to properly inform all involved parties which requirements are made with respect to their delivery and the installation work.

5.3. EMC implementation plan

The control plan states "what needs to be done to prevent interference", but not in detail "how this should be done". This subject will be dealt with in the implementation plan. An implementation plan gives for example information about: how to arrange cables into different groups with roughly the same disturbance levels, separation distances between those cable groups, preferred communication busses and so on. With this information installers / system manufacturers can create electrician's manuals / instructions. An electrician's manual states in detail "how the components that will be used need to be installed". Items to be discussed: whether earth connections should be made inside or outside a cabinet, how an EMC gland needs to be mounted, where to earth cable screens and so on. It is important that requirements are specific and measurable, so it is easy to verify whether the work has been performed correctly.
The equipment manufacturer's installation instructions can conflict with the requirements from the EMC control plan. In this case a memo will be added to the implementation plan. This memo explains: how the conflict is to be dealt with, what the chosen solution is, what the consequences are and who is responsible for implementing the solution. An example is when the equipment manufacturer requires the earthing of the cable screens at only one point, whilst the EMC control plan states that they are to be earthed at multiple points.

5.4 EMC validation and verification plan

The test plan exists of two major parts a verification part, primarily performed during construction phase and a validation part, primarily performed during harbor acceptance and sea acceptance trials.
The verification is all about checking if the best practices are implemented correctly and if the instructions from the electrician's manual are lived up to. This needs to be done during the construction phase because for example: "after an EMC gland is mounted, it is hard to see if this was done properly". The same applies for topics like: creating earth connections, cable separation and so on.
The validation is performed to check if the best practices are as effective as expected. Simple tests can determine this like checking the throughput of data busses, checking reception of radio signals, measuring noise levels in receiver bands, etc.

6. Conclusion

The risk-based versus the rule-based approach to achieve electromagnetic compatible complex systems has been described. The reasons for using the risk-based approach is described from a legal and a cost perspective. How to implement the risk-based approach for complex systems is described using a naval ship as an example. The four EMC engineering activities for such a platform are EMC management, EMC control, EMC implementation and EMC validation & verification. These activities have been described briefly.

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