E^3 Concerns For The Military Use Of Commercial-Off-The-Shelf (COTS) Equipment

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Abstract — The use of Commercial-Off-The-Shelf (COTS) equipment on military platforms is expected to significantly increase as Secretary of Defense Perry's acquisition reform initiative continues to be implemented. Recent COTS installations on military platforms have demonstrated both the expected performance and time-to-develop improvements as well as some unexpected problems due to electromagnetic environmental effects (E^3) emission or susceptibility problems. Rapid response electromagnetic interference (EMI) reduction teams have been able to successfully apply traditional DoD E3 installation and design techniques to restore (some of) the system performance. These lessons learned experiences have shown that program managers can neither ignore E^3 requirements nor simply specify existing commercial EMI requirements. In order to minimize the potential negatives due to the use of COTS equipment, it is necessary to analyze the causes of the existing problems and develop a methodology to minimize or eliminate similar E3 problems from occurring on future military platforms.

INTRODUCTION

This paper will: (1) detail two recent COTS E^3 problems, (2) discuss the recently measured EMI characteristics of commercial VME/VXI chassis's/cards, (3) comment on the significant differences between commercial and military EMI specifications and (4) describe a recommended E^3 approach to minimize or eliminate similar occurrences. This approach should reduce the number of new EMI problems that are expected to increase proportionately with the increased use of COTS systems aboard military platforms. This new approach will be accomplished by: (1) evaluating the operational EM environment and the systems performance goals in order to select an appropriate mix of commercial and military specifications, (2) proposing a combination of up-front E^3 analysis & prediction combined with early EMI testing on "high risk" equipment's or systems, (3) utilizing follow-on "super cabinet" or system level E^3 tests (in lieu of extensive unit level tests) and (4) using an EMC process action team (PAT) team as an Advisory Board to ensure the effectiveness of E^3 efforts over the development of the platform. This approach is expected to provide a cost effective E^3 control program that will allow us to emphasize and take maximum advantage of recent improvements in commercial E^3 requirements, such as the soon-to-be updated ANSI C63 Requirements.

Expectations are that with the change in approach of the E^3 Control Program, many commercial equipment can be used "as is" while others will require minimize changes to obtain full performance in the military EM environment. It is believed that this approach will be in harmony with the Secretary of Defense's thrust on acquisition reform regarding the use of performance specifications and the procurement of commercial equipment for military use.

COTS EQUIPMENT-MILITARY INSTALLATION E^3 PROBLEMS

Several examples will be used to illustrate the concerns associated with the use of commercial equipment on Naval platforms. The lessons learned from these shipboard EMI experiences are considered a precursor of problems that easily could be generic COTS problems.

A COTS EMI Source: A commercial static variable frequency controller was installed aboard a Naval platform and quickly became both a radiated and powerline conducted major EMI source [1]. This EMI source is typical of many that occur in below deck areas; radiated low frequency magnetic fields and powerline conducted noise, both differential and common mode. Because this controller was a commercial unit it had neither conducted nor radiated EMI requirements above 2 kilo Hertz. Significant performance degrading EMI coupled into many shipboard systems including sonar, video cameras, motor controllers, including critical maneuvering controls indicators. Powerline harmonic voltages and currents, both differential and common mode, were significant contributors to the degradation. The radiated low frequency noise was fifty-four decibels above the Mil Std 461C RE-01 EMI limit which is still recommended for below decks equipment.

A COTS System Susceptor: A commercial SHF communications system was installed by the manufacturer aboard a Naval platform with (initial) disastrous results. For the commercial manufacturer this installation was a high visibility, high risk, high payoff venture where success was worth millions and failure nothing. A COTS system that communicated in the commercial environment at 128 kilo baud/sec, with low bit error rates (BER's), could only perform at 9.6 Kilo baud/sec with marginal BER's. This initial performance, at $1/13^{th}$ the commercial performance, was certainly unacceptable. This was primarily due to the lack of contractor knowledge of the shipboard powerline, EM environment and typical EMI coupling mechanisms. After the completion of a joint Navy/contractor team EMC effort [2],the modified system accomplished "acceptable performance" by communicating at 32 to 64 Kilo baud/sec with "acceptable" BER's.

COTS E^3 Observations: This type of very expensive, E^3 corrective actions cannot be the normal method to ensure performance for future COTS installations. Therefore it is imperative that the lessons learned from these efforts be examined to determine the most appropriate and most cost effective methodology to be used to guarantee the performance of commercial system installations. As a short term solution this very expensive fix-it effort did more to demonstrate the Navy/contractor teams abilities to rapidly resolve E^3 problems than it did to demonstrate the ability of commercial equipment to operate in the military E^3 environment. In addition, short term E^3 solutions often cannot be relied upon to provide long term/life cycle performance guarantees as you would expect from a properly designed E^3 installation. There are several key observations that can be made from these two COTS installations:

(1) COTS equipment may not work (without modification) unless the expected military E^3 environment is considered, (2) Unlimited resources can make almost any system operate at least reasonably will for short periods of time, and (3) Short term solutions (fixes) should not be expected to perform well over the platforms total mission period.

More COTS E^3 Problems ? These two E^3 problems are just several recent examples of performance degradation due to the use of COTS equipment. NUWC has also been involved with E^3 efforts associated with other COTS systems, including an RF communications system, numerous commercial CRT displays, a ships entertainment system, (ship communications) and some US Coast Guard systems.

When we examine the E3 requirements imposed on many commercial equipment's it is seen that many have had little, if any, susceptibility evaluations or requirements. Most have had only electric field emission requirements, such as those required by the FCC specifications. In addition, many commercial equipment utilize non-metallic materials in their construction to reduce both weight and cost. These materials have shown the following E3 properties that make them risky to use aboard military platforms: (a) negligible magnetic field shielding effectiveness, (b) low and sometimes short term Electric field shielding effectiveness, and (c) material grounding problems associated with EMI, ESD, and safety issues. It is possible that without proper attention these materials may be the "Achilles heal" of commercial equipment. The Navy has developed

COTS Chassis'	COST	Test Conducted To Chassis Under Full Load (Pass/Fail)				
		PowerFactor	CE101	CE102	RE101	RE102
UNIT A: 500W 20 Slot VME Chassis	$5,200.00	-0.705	Fail 60Hz Harmnc. < 8dB	Fail Switch. Freq. 43kHz < 5dB	Pass	Pass
UNIT B: 500W 15 Slot VME Chassis	$9,600.00	-0.715	Fail 60Hz Harmnc. < 25dB	Fail Switch. Freq. 42kHz < 9dB	Fail Switch. Freq. 43kHz < 12dB	Pass
UNIT C: 1 900W 14 Slot VME Chassis	$14,000.00	-0.743	Fail 60Hz Harmnc. < 25dB	Pass	Pass	Pass
UNIT D: 900W 20 Slot VME Chassis	$14,200.00	-0.748	Fail 60Hz Harmnc. < 25dB	Pass	Pass	Pass
UNIT E: 500W 15 Slot VME Chassis	$25,000.00	0.996	Pass	Pass	Pass	Pass
UNIT F: 600W 13 Slot VXI Chassis	$6,500.00	0.760	Fail 60Hz Harmnc. < 8dB	Pass	Fail Switch. Freq. 67kHz < 7dB	Pass
UNIT G:1000W 13 Slot VXI Chassis	$7,000.00	0.729	Fail 60Hz Harmnc. < 20dB	Pass	Pass	Fail Broad Band 80MHz < 5dB

Figure (1). Summary Of Recent VME/VXI EMI Tests

and Patented [3, 4, 5] various materials, improvement techniques, and EM models to help ensure the compatibility of such composite materials.

Examination of both the commercial European Norm and the ANSI C63 12/2 EMI requirements illustrate significant weaknesses in areas considered so crucial to military platform compatibility. These crucial weaknesses are related to; (1) low frequency magnetic fields, (2) low frequency conducted powerline noise (f<150 kHz), and (3) ground plane noise. When these weaknesses are considered with other military platform critical E^3 factors, such as, increased power density and the trend toward integration of many functions within the same enclosure, the potential for E^3 problems increases.

Todays reduction in military budgets and the reduced use of unit level EMI tests are additional factors of concern. The increasing military reliance on the utilization of commercial equipment, such as VME/VXI electronics, is of some concern based on recent EMI tests [6] that NUWC has conducted on these devices. Figure (1) provides a summary of recent EMI tests conducted on commercial VME chassis's by the NUWC EMC Branch . These chassis's range in power from 500 to 1000 watts, in slots from 13 to 20, and in cost from $5,000 to $25,000. Even with some commercial E3 attention, some of these units are failing in E3 area's that traditionally have created shipboard EMI problems. For example, low frequency power line harmonic failures range from 8 to 25 dB, while high frequency failures ranged from 5 to 9 dB. Several chassis's, particularly the less expensive units, have had magnetic field failures at switching frequencies. These failures may weaken the VME/VXI commercial backbone of our future systems.

E^3 LESSONS LEARNED

These military platform EMI reduction efforts, EMI measurement results and EMI requirements analysis indicate the following facts: (1) not all COTS equipment will function in the military environment without modification, (2) commercial EMI specifications may have serious weakness for military platforms, (3) inadequate concern is shown for common-mode EMI coupling effects, and (4) COTS systems need to consider unique military environmental concerns.

Performance degradation has been caused by the lack of understanding about ungrounded power, cable run EMI coupling, non-zero groundplane voltages, and power factor problems. These facts identify the need to evaluate the E^3 risk of using COTS equipment as early as possible as well as the potential need to apply design changes in those equipment found to be either susceptors or emitters.

COMMERCIAL-MILITARY PARTNERSHIP TO IMPROVE COTS PERFORMANCE

In today's marketplace the military needs no longer dominate a companies interests, therefore military COTS equipment must be either used "as is" or it must rely on the commercial partner to willingly change their equipment. Such a partnership has and is occurring with the development of commercial CRT displays that will be used aboard various military platforms. Most commercial CRT's are designed to operate in the .5 Gauss earth's dc field rather than the expected 5 to 20 Oersted shipboard fields. Navy testing of typical CRT displays in an " average" 5 Oersted field produced the completely unusable splotchy CRT display shown in figure (2) rather than the expected uniform red screen. A performance based requirement, based on the expected shipboard levels, was identified by the Navy while various vendors willingly and at their own expense modified their systems in order to meet the more stringent military needs. Cooperation between the Navy, who developed a computer driven shipboard dc field simulator, and the vendor, who developed the self contained compensation/degaussing systems yielded a commercially available system that will perform reasonable well in the average level fields.

APPROACH TO ACHIEVE COTS E^3 SHIPBOARD COMPATIBILITY

To achieve COTS equipment compatibility on military platforms requires a thorough E^3 approach to mitigate the increased risk of incurring performance degradation. This approach should ensure that the platforms performance requirements drive the E^3 requirements. To ensure against over-specification, both mission critical & non mission critical requirements must be considered and identified. The use of commercial E^3 requirements must be examined and used wherever possible. The E^3

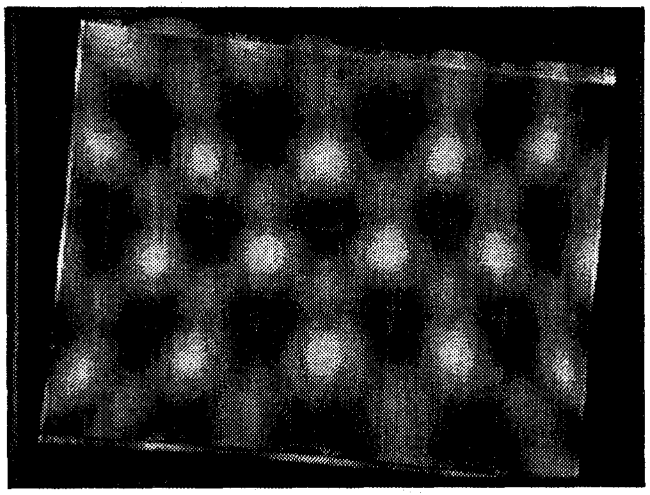

Figure (2). COTS CRT "Uniform Red" Display In Shipboard 5 Oersted DC Field

requirements have to be a part of the system/platform functional requirements document (FRD). In addition, a process action team (PAT) typically identified by E^3 personnel as an EMC Advisory Board (EMCAB) should be utilized to take advantage of "lessons learned". However, this EMCAB will not be the "EMCAB-of-old". EMI tests will be specified to be more system or compartmental in nature in an effort to reduce EMI test costs. Early unit level tests will only be conducted on high risk commercial or military systems that have a history of EMI problems.

In summary, in order to control costs we need to establish a E3 program with (1) selective use of an EMC analysis & prediction capability, (2) selective early unit level tests on high risk units/systems and (3) the use of system level tests-vs.-unit level tests (at integrated test or landbased facilities) whenever possible. The Intelligent EMC Analysis & Design System (IEMCADS) program [7], was developed by NUWC & Kaman Sciences to support the need for a tool to conduct both cabinet level and compartmental level EMC analyses. This EMC capability will be made available free of charge to users with a government contract.

Specific E^3 Issues: In addition to the general approach just discussed, there are specific COTS E^3 concerns that will need to be addressed regarding: (1) the use of non-metallic enclosures in a military environment, (2) the expected increase in electromagnetic radiation and susceptibility from the COTS equipment and, (3) an approach to handle the change in E^3 practices as a result of our transition from individual equipment cabinets to large integrated enclosures. It is expected that the first two items will be handled with the proper amount of traditional E^3 attention, however the large "structurally integrated enclosures" will require unique attention. As shown in figure (3) these large "supercabinets" will force the integration of many previously independent functions/operations into one cabinet in order to have the COTS equipment satisfy other military requirements, especially shock, at the supercabinet level rather than the unit level. What has not yet been addressed adequately is the changes needed within and external to the supercabinets related to E^3 design.

EXAMINE INCREASED USE OF OMMERCIAL E^3 REQUIREMENTS

Although the DoD E3 community realizes that it can still use the MIL STD 461 requirements and 462 test procedures, it is really not consistent with Secretary of Defense Perry's acquisition reform initiative to do so. If the E3 engineer compares some of the new commercial E3 requirements with the military E3 requirements, they will would find that except for low frequency radiated, ground plane and powerline area's the commercial specifications can be very similar to the military specifications. Examination of the soon to be released ANSI C63 requirements (said to be an Americanized version of the European Norms) will demonstrate that closeness. For a recent submarine platform, a mixture of both commercial and military requirements were specified [8] based on the platforms

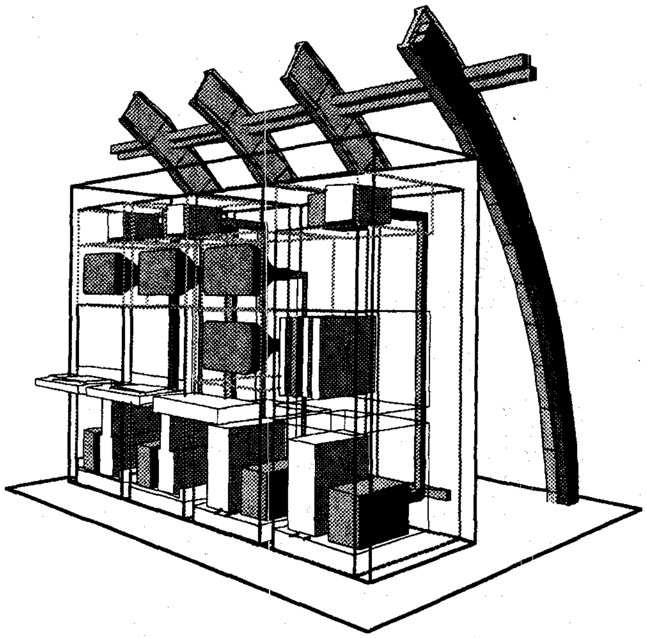

Figure (3). EMI View Of Structurally Integrated Enclosure "Super Cabinet"

performance needs. Figure (4) illustrates the selections. Seven ANSI C63 12/2 requirements were selected as desirable when combined with seven Mil Std 461 requirements. It should be noted however, that the frequency range on many of the ANSI requirements were lowered for Naval use.

Additional reasons to consider using a mixture of both military and commercial E^3 standards follow: (1) if a company is required to meet either the European Norms (or the ANSI C63) requirement in order to sell products to the commercial market, then they probably won't mind meeting it for Uncle Sam, (2) for many of us in the E^3 community, obtaining some EMI data (commercial) is always better than obtaining no Mil Spec data (which happens when all Mil Spec tests are waived due to schedules or budgets). It should also be noted that some commercial E^3 requirements actually exceed the Mil Spec E^3 requirements. In addition to using commercial requirements, additional money and time can be saved by conducting some EMI tests during the system performance test period.

CONCLUSIONS

As stated herein, there are some good points and some bad points about using commercial equipment aboard military platforms. The obvious benefit is that we can speed technology into the military, typically at lower cost. However if we don't do this smartly we can expect to lose the technological edge we obtain by using the commercial equipment due to degraded performance from EMI coupling. If we consider E^3 early and imploy proper E^3 installation design techniques it is believed that many commercial equipment can be used "as is" or at least with a minimum number of engineering design changes. The only other avenue is to leave the problem resolution to the traditional "fix it" teams.

The envisioned hard spot in this effort will be the required development of joint military commercial EMI test procedures.

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Nomenclature	Test	Frequency	Comments
	Radiated Emissions:		
N-RE-01	Magnetic field	60Hz to 100KHz	No Commercial Requirement
N-RE-ANSI	Electric field	10KHz - 1GHz(1m)	10K-0.8MHz info. only
	Conducted Emissions:		
N-CE101	Power line	30Hz to 10KHz	No Commercial Requirement
N-CE-102	Power Line	10K to 10MHz	
	Radiated Susceptibility:		
N-RMF-ANSI	Magnetic Field	60Hz	test by NSSN-RS101
N-RS101	Magnetic Field	30Hz to 100KHz	No Commercial Requirement
N-RI-ANSI	Electric field	10KHz to 1GHz	10K-0.8MHz info.only
N-DCMF	DC Magnetic field	level=5 oers/sec	No Commercial Requirement
	Conducted Susceptibility:		
N-CS101	AC and DC Power Lead	30Hz to 50KHz	
N PFCM-ANSI	Power frequency c.m.	57Hz to 60Hz	10v
N-CS06/FT-ANSI *	Power Line Spike *	-------	No Commercial Requirement
N-CS109	Structure Current	60Hz to 100KHz	No Commercial Requirement
N-RFCM-ANSI	Radio Frequency C.M.	150KHz to 100MHz	
N-FT-ANSI	Fast Transient C/D M.		
	Electrostatic Discharge(ESD):		
N-ESD-ANSI	Electrostatic dis.	------	Contact(4KV), Air Discharge (8KV)
	ADDITIONAL TESTS FOR COMMUNICATIONS ESM IMAGING SYSTEMS:		
N-CE106	Transmitter	10KHz to 40GHz	
These req./tests will be accomplished during system Performance Verification Testing: RE103, CS103/4/5			
FOOTNOTES: 1. Bold = Commercial Requirement 2. * test by N-FT-ANSI			

Figure (4). Recommended Military Commercial E^3 Requirements Mixture

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