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White Paper

EMP Mitigation

Protecting Land Mobile Vehicles from
HEMP Threat Environment

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Protecting Land Mobile Vehicles from HEMP Threat Environment

Abstract

This paper discusses the possibility, requirements and necessary steps to protect land mobile vehicles from the effects of an electromagnetic pulse event to ensure continuous mobility of the vehicle. While this discussion applies to civilian and military vehicles alike, the defense industry's recognition of a general EMP (electromagnetic pulse) / HEMP (high-altitude electromagnetic pulse) threat has long resulted in the establishment of military standards that set requirements for effective EMI/EMP hardening of critical defense systems. As such, the applicable military standards MIL-STD-188-125 and MIL-STD-464 are being referenced in this discussion.

Introduction

The realistic threat of an Electromagnetic Pulse (EMP) or High Altitude Electromagnetic Pulse (HEMP) event – natural or man-made has been widely recognized by several government related agencies such as the U.S. Congressional EMP Commission, the Defense Nuclear Agency or the Defense Threat Reduction Agency. Potential long-term disruptive effects on our society have also been acknowledged and protective and counter measures are being increasingly implemented. While most hardening efforts focus on mission critical electronics, mainly meaning C4I (Command, Control, Communications, Computer, and Intelligence) systems, protecting continuous mobility has attracted heightened attention as well.

From a theoretical standpoint, the very simple condition that would provide complete EMP protection to land mobile vehicles is to park all critical and vulnerable assets in a suitable metallic box or EMC (electromagnetic compatibility) tight chamber, also referred to as Faraday shield. At this point, doing so would translate into parking the entire vehicle in an EMC shielded garage. However, even though transistor driven radio, power and control electronics deployed in modern day civilian and military vehicles are highly vulnerable to electromagnetic damage, C4I equipment can obviously not be parked in an EMC tight chamber while effectively performing operations. Quite contrary, it is often deployed in harsh environments, possibly during critical civil defense or disaster scenarios where failing is not an option. In addition, continuous mobility of the vehicle itself is most likely of critical importance to mission success.

Transtector and PolyPhaser offer a wide range of products to effectively protect the C4I systems deployed in these vehicles. This article, however, is intended to open discussions about the challenges of protecting land mobile vehicles from the effects of the EMP/HEMP threat environment for the purpose of retaining mobility.

Design Requirements

Any discussion about the protection of land mobile vehicles from HEMP effects should consider the guidelines set by applicable military standards, in this case MIL-STD-188-125 class of standards as well as MIL-STD-464. The MIL-STD-188-125 class of standards establishes minimum requirements and design objectives for EMP/HEMP hardening of fixed and transportable ground-based systems. It is further amended by Appendix A for Shielding Effectiveness, Appendix B for Pulse Current Injection and Appendix C for Continuous Wave Immersion. MIL-STD- 464, on the other hand, provides basic requirements for electromagnetic environmental effects (E3) considerations for Department of Defense Systems. Its primary intent is to provide guidance and test methods for electromagnetic threats at the system level.

While facilities and systems required to fully comply with these provisions are generally designated by the Joint Chiefs of Staff, a Military Department Headquarter or a Major Command, these guidelines set design standards that should be considered for any effective EMP/HEMP hardening effort of any system.

In addition to previously mentioned MIL standards, various IEEE, IEC, and NATO standards identify testing and hardening requirements as well. These should also be understood and strictly adhered to in order to construct and maintain protection enclosures and surge-filter systems that successfully repel natural or intentional EMP threat events.

For a land mobile vehicle, testing according to the MIL-STD-188-125 class of standards generally boils down to examining the shielding effectiveness1 and pulse current injection response of the system2. These tests validate the electrical shielding and surge mitigation integrity of the system.

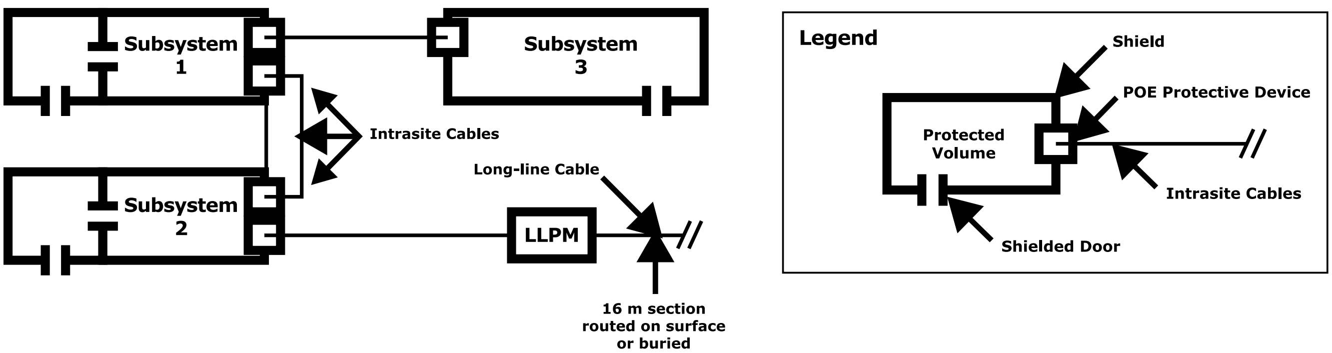

Figure 1: The basic premise of shielded enclosures and screened environments is to create “Faraday Cages” at each separate subsystem with filters applied at all point of entry (POE) for cable runs between enclosed regions.

Keeping all applicable military and commercial standards in mind, effective hardening of system components requires adherence to the following three basic design practices:
(Illustrated in Figure 1)

- Construction of Faraday shield environments (EMI tight boxes) around all critical systems
- Bounding of all metallic structures to a single point ground system
- Surge-filter protection of all entry/egress points that provide electronic connections between these shielded environments

Analysis of EMP Vulnerable Parts and Application of EMP Hardening Design Principles

To meet our objective of keeping the vehicle moving through an EMP assault, we will first have to look at an analysis of the electrical system to determine which components are sensitive to damage and should therefore be placed into a Faraday shield environment.

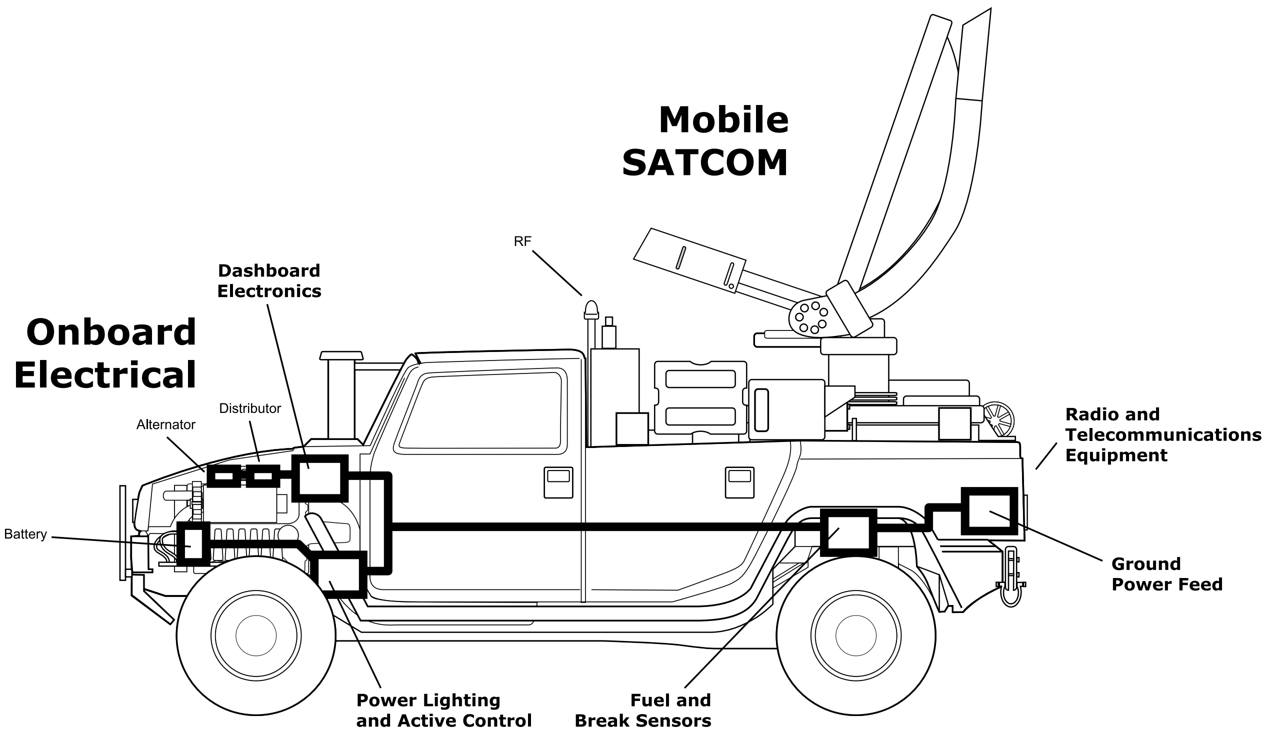

Figure 2 shows an overlay of the necessary “Faraday Cage” constructs at each critical subsystem of the vehicle, with bonding between systems and filters at each POE.

The battery and alternator form the basis of the DC power plant. The alternator is basically a generator that siphons rotational energy from the combustion engine and includes a voltage regulator to stabilize the electrical voltage while the vehicle is operating. Note the negative electrode bonding connections to the auto chassis. All of these components can be considered immune to HEMP damage.

The ignition system on the other hand could be either vulnerable or resistant depending on the type of system. Our analysis of the ignition system presumes the application of the SAE J1939 protocol, which is a standard used for communication and diagnostics among modern computerized vehicle components. Older diesel engines lack the computerized fuel management and ignition systems of modern vehicles, which in turn make them much more reliable under EMP conditions.

The SAE J1939 protocol operates at less than 5Volts/200mAmps between the distributer computer systems in the vehicle. Some of the typical electronic modules within such a modern internal communications network and governed by this standard are the Engine Control Unit (ECU), the Transmission Control Unit (TCU), the Anti-lock Braking System (ABS) and body control modules (BCM). Furthermore, C4I systems deployed in defense vehicles have also become amazingly elaborate, incorporating point-to-point radio, satellite uplink, weapons and counter-measure electronics, all of which share a basic sensitivity to EMI interference and HEMP damage.

The ignition system (Illustrated in Figure 3) produces a high voltage electrical charge and transmits it to the spark plugs via the ignition wires. The charge is generated by the ignition coil and fed to the distributor.

Like mentioned above, in modern vehicles, a computer controls the timing and output of the charge to the spark plugs in each combustion cylinder. This computer governs a score of variables including timing, fuel mixture and monitoring functions and is therefore an obvious candidate for HEMP protection and Faraday cage construction. The ignition coil and spark plugs on the other hand are considered immune. The challenge though is to protect the 20kV lines connecting the ignition coils (controlled by the computer) to the spark plugs. Sufficient isolation must be integrated into the control design between the plugs and the ignition system computer.

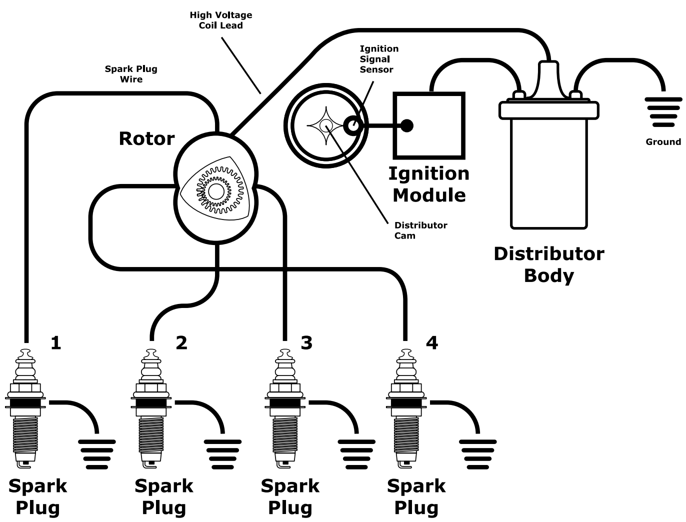

Figure 3 shows a simplified ignition system with key features including ignition control lines and high voltage spark plug connections. The ignition module represents the computer that controls among other things timing and output of the charge and should be protected through a Faraday Cage construct.

So while batteries and alternator devices can be considered immune from EMP damage, radio and transistor based control systems are generally vulnerable. These sensitive computer systems are typically scattered around the vehicle engine, dash board and payload compartments. Each critical subsystem would thus require a Faraday cage construct and bonding to the electrical ground of the chassis with filtering and surge protection at each point of entrance. (See block diagram in Fig 2)

Control lines connecting the network devices can be routed through welded conduit runs between shielded enclosures. The ports of penetration through each enclosure to a control or sense mechanism are point of entry targets for series conductive bulkhead mounted filter-protection elements. The use of overbraid cable could be implemented to improve shielding.

Finally, to close our discussion on effective EMP hardening of a vehicle's vital components to maintain mobility, we need to look at grounding - bonding of all metallic structures to a single point ground system. All previously discussed electrical faraday shield systems need to be permanently and substantially bonded to the chassis frame. Much like an air borne or space borne electrical system, the chassis is isolated by the insulation of the tires and floats relative to the earth ground. Following the route of the control system wiring between the alternator, the power plant and the ignition system's control transistor circuits, a Faraday cage (enclosure) must be constructed around that computer. Lastly, all wire penetrations need rigorous filtering and protection in order to mitigate any unintended conducted energy that has coupled onto the wiring system via the electromagnetic threat.

Conclusion

While the effects of an EMP/HEMP event on our society have been widely discussed and countermeasures have been mandated for most defense related C4I equipment as well some commercial applications, the significance and practicality of EMP hardening of a vehicle to maintain mobility through an EMP attack has not been given much attention so far. This may be due to the fact that older diesel style engines are virtually HEMP proof and only the advent of the modern computerized electronic ignition systems have made this discussion necessary. The importance of uninterrupted mobility to our modern society is indisputable and quite comparable to that of energy and communication as it applies to military and civilian systems to avoid chaos after a large scale EMP event. However, with sensitive computer systems being scattered around the vehicle, each of them needing it's own Faraday construct and rigorous filtering of all wire penetrations, the sheer complexity of the protection design challenges the practicality of EMP hardening of land mobile vehicles.

As discussed in this article, the sensitive systems can be identified by the presence of any microelectronic control components and are inherently susceptible to the high voltage electric field environment of a HEMP phenomenon. Following the design principles outlined in this article, these systems can be protected. Practical demand from national and international defense industries and civilian sectors alike in the years to come will determine future availability and marketability of land mobile vehicle HEMP protection solutions.

References

1. Mil-Std-188-125 – Appendix A – Shielding Effectiveness (SE)
2. Mil-Std-188-125 – Appendix B – Pulse Current Injection (PCI)
3. Mil-Std-188-125 – Appendix C – Continuous Wave Immersion (CWI)
4. Mil-Std-188-125-2
5. Mil-Std-464
6. IEC 61000-5-2
7. SAE J1939 protocol

Please contact us for questions or further information on this topic.

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