IMPACT OF INADVERTENT ELECTROMAGNETIC EMISSIONS ON ORGANIC VEHICLES THAT AFFECT THE TACTICAL COMMUNICATIONS OPERATING BANDS

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Abstract

This paper will discuss inadvertent electromagnetic compatibility issues between communication systems, electrical components in tactical vehicles. These inadvertent electromagnetic interferences (EMI) are attributed to the potential system performance degradation to communications. This paper will provide a practical engineering approach to mitigate EMI issues. Traditionally EMI issues were dealt with by applying Military Standards (MIL-STD). However, it is important to point out that meeting these MIL-STD on individual system level doesn't necessary imply system integrity is maintained when integrated with other systems. The integration of multiple systems in a common platform is why EMI issues must be evaluated as integrated by a different approach. The EMI mitigation techniques discussed in this paper should be adopted by integrators as standard practices and procedures used during development and integration of new tactical vehicles. In summary this paper will highlight engineering solutions to help lower EMI emissions and develop good practices to be implemented in the family of tactical vehicles.

Introduction

The scope of this paper is to make vehicle integrators aware of better engineering techniques and procedures that will help build more efficient tactical vehicles from a communications perspective. As more electronic devices and systems are being incorporated and adapted into military systems and operations; challenges with radiated emissions (RE) have drastically increased. Any flow of electricity may cause inadvertent emissions; for example are arcs in motors and lights, internal clocks on computerized devices, and power converters. These emissions, broadband or narrowband may produce (EMI) when they are present in tactical operating bands. In the past these problems were dealt with by applying (MIL-STD) to help limit the allowable emissions generated by certain equipment.

It is important to keep in mind that EMI can become a greater problem when many systems are connected together or if they are installed differently from what they were originally intended. This is why on the move (OTM) systems and tactical vehicles have to be designed and integrated with much care if electromagnetic compatibility (EMC) is to be achieved. EMC is the ability of a radio system to operate in its intended environment without suffering from interference from other systems and without causing interference to other systems. The tactical vehicles studied are currently being fielded in significant numbers therefore this situation should promptly be assessed to ensure not only safety but also to improve the overall performance of our forces.

Understanding the Issues

Because their missions are so wide these families of vehicles differ not only in size and shape but also in the way the electrical components are configured in the organic (base) vehicle. Some components may have a different manufacturer for the same type of sensor. Others may have a different load requirement resulting in a different electrical power need. Different integrating teams may have a different integrating approach where information is not usually shared with other organizations. To study the effects of the different components and facilitate the engineering evaluation of the base vehicles two tests were performed a radio desensitization test and an EMI study. The desensitization test would show a general area of potential emissions and the EMI study would go in depth to specifically target emitters and find a possible solution.

The Engineering Approach

Desensitization

The objective of performing a communications desensitization test is to identify if any degradation occurs in the radio link when different systems are energized or operated in close proximity to other radios and antennas.

Basic desensitization test setup consists of connecting an analyzer (audio, BER (bit error rate) hardware or software) to the receive victim radio under test which measures the received signal. A signal or bit generator is connected to a remote radio to generate a stream of data, analog or digital, for the radio to transmit. The transmit radio connects to an antenna inside an anechoic chamber through a series of cables and attenuators. The attenuators allow control over the power of the transmitted signal and simulate large distances between radios to measure critical points near the limits of communication. (Refer to Fig. 1)

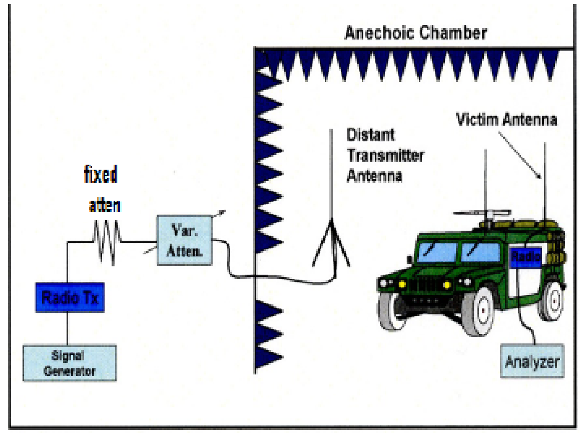

Figure 1: Basic setup for a desensitization test.

EMI Study

This study, through experimentation, detects possible areas of EMI vulnerability and identifies solutions to reduce unintended radio frequency (RF) emissions into the system. The EMI study is generally performed after a desensitization test on target areas by using near field probes and current clamps to identify sources of high emissions. With the aforementioned instruments, RF noise can be traced and pinpointed to a single source. After exposing the emitting source, RF "quieting" is performed (refer to recommendations section). Subsequently the desensitization test is repeated to validate system improvement. The EMI study next analyzes the results and provides recommendations. The problem areas can by treated with different approaches including mitigation techniques and by formulating Tactics Techniques and Procedures (TTPs).

Part of mitigation techniques and TTPs is to know where the tactical bands are located for your particular application. This knowledge will help determine where improvements need to be made. The high frequency (HF) band is located between 2-30MHz; the Single Channel Ground and Airborne Radio System (SINCGARS) band is between 30-88MHz. The very high frequency (VHF) band covers approximately 30-300MHz, the satellite communication (SATCOM) band covers from approximately 240-320MHz, and the ultra high frequency (UHF) band covers from 300-3000MHz. Vehicle generated emissions generally are most troublesome at lower frequencies (HF, VHF), however in particular cases emissions above 3 GHz are also explored.

Issues from Base Vehicle Components

Tactical vehicles and individual components are habitually tested for radiated emissions using the MIL-STD 461F for regulations of RE 102 (Radiated Emissions limits). For the most part radio sensitivity levels may be more sensitive than this level by tens of dB depending on the radio. Even though the vehicle may have passed emissions test, vehicle systems still desensitizes the onboard radios as a result of radio sensitivity levels. Analysis on many vehicles showed to have high levels of RF noise in similar configurations: Such as turning on master power, the engine, the air conditioner (AC), and lights. Further studies showed the following vehicle components to produce high emissions: voltage equalizers connected to the batteries to assist with charging, sensors, A/C fan motors, wiper motors, and lights.

Many vehicle components work off of 12VDC rather than the 24 VDC vehicle supply. To achieve 12VDC, the vehicle batteries are connected together in series and centered-taped. The center-tap configuration drains the batteries unevenly and may result in problems when charging. To balance the charge and the load in the batteries a battery equalizer is used. These equalizers have shown to produce high levels of broadband RF noise that affect the tactical communication bands. When the master power is engaged, power flows to the main distribution panel and from there to sensors, switches and finally to most vehicle systems. These sensors have clocks inside allowing them to talk to the vehicle computer. Many times these sensors create RF noise that may couple to other systems because many systems are connected through the same wire harness.

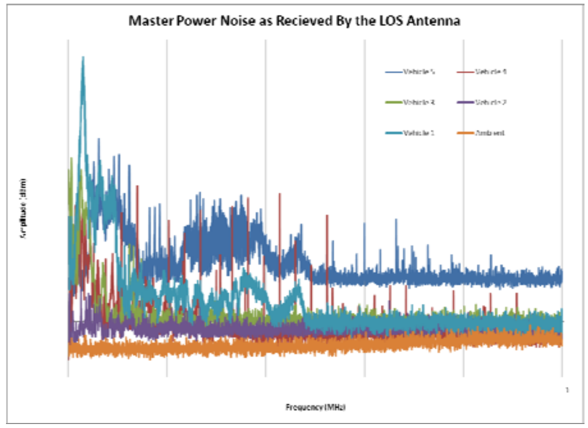

Figure 2: RF noise from the master power in different vehicles.

RF noise may couple to other cables when the cables travel along the same path. The RF noise tends to be discrete (single frequency or narrow banded) but repeats itself many times in a single band which can be a problem if the communications systems need to utilize any of the affected frequencies. When the engine turns on a rise in the RF noise floor is seen. Further investigation has shown the alternators to cause most of the noise seen in this configuration. The alternator is a key component in the base vehicle. To select the appropriate one it must be compatible with many specifications like voltage rating, continuous Amp capacity, and battery type. Continuous Amps should be considered over peak Amps because alternator can only deliver peak Amps over a very short time. On the other hand, battery type is important because different batteries release heat differently, this will affect the way they can be charged, and thus the alternator should be compatible with the battery type.

Another common system that has shown to generate RF noise in the tactical communication bands are the lights. The lighting systems might incorporate different technologies depending on the use. These may range from the incandescent, light emitting diodes (LED), high intensity discharge (HID), fluorescent, xenon, and many others. Many times when the lights are turned on high levels of broadband RF noise are observed in the communications bands. Some of the known EMI related issues with lights tend to come from voltage conversions from one voltage level to another, or from the high capacity arc (typically created in the ballast) used to illuminate a vapor tube type light. Both these processes may cause unwanted radiated emissions in the system which may radiate out and potentially affect the communications band.

Electrical arcs are another big problem since they generate broadband RF noise that has shown to affect the communications band. Arcs are found in motors such as the wipers and the A/C. The RF noise in the wipers tends to be more discrete because of the on and off behavior of the wipers. The discrete RF noise covers a wide variety of frequencies affecting many tactical bands. The RF noise in the AC system tends to be more broadband and constant (Refer to Fig. 2). The AC system tends to have very high RF noise emissions because the AC system has many motors distributed in the tactical vehicles. The AC system has fan blowers and condensers which have motors. Typically tactical vehicles have two AC units.

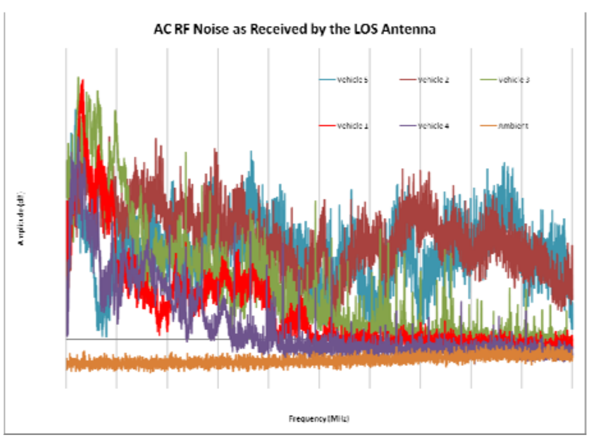

Figure 3: RF noise from the AC in different vehicles.

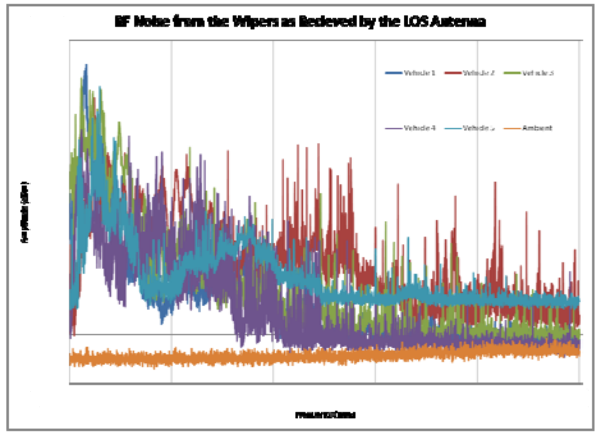

Figure 4: RF noise from the AC in different vehicles. ***(It is shown how the AC system may degrade all communications band as shown, HF, SINCGARS, VHF, SATCOM and UHF)***

Recommendations

Whenever possible, procure vehicle components with the most stringent EMI specifications available. When it's not possible to procure EMI quiet components there is a need to "quiet" the items in circulation. There are many ways to minimize the overall effect of the RE generated in the vehicle systems. A few simple guides are the use of proper connectors, shielded cables, and cable routing. These techniques will ensure that RE does not leak at the connector end, nor it will be emitted by the cable because the shielding will prevent it. The cable routing will prevent the RF noise to couple to other cables and affect adjacent systems. The usage of bulkhead connectors will further reduce the EMI traveling in a cable. It is recommended to use short cables and bulkhead connectors when crossing vehicle compartments instead of long cables. The shorter cable along with the connector will help channel the RF noise traveling on a line to ground.

Grounding is essential to reduce RF noise. When grounding, it is important to ensure that all components have a designated ground strap. Grounds and bonds should be measured to ensure proper path to the vehicle chassis. It is recommended to have 2.5 milli-ohms or less resistance across faying surfaces and less than 10 milli-ohms from any connector to ground. Note: a typical ohm meter is not recommended to make these types of measurements. A special milli-ohm or micro-ohm meter should be used. These meters have special probes which make a bridge circuit thus allowing the meter to eliminate resistances within the cables or the contact points. If a bolt is used as a ground point it is very important to mask the paint from where the bolt will be placed to ensure metal to metal contact. When working with an enclosure, it is important to make sure the side panels should have proper metal to metal contact and if possible install EMI gasket between the panels. The metal to metal contact or EMI gasket will prevent RF noise generated inside the box from leaking out.

It is also recommended to place all electrical components inside a faraday-cage (a metal box-like enclosure which eliminates the free radiation of electromagnetic noise away from the component). Faraday gages are recommended especially for some electrical components and sensors having a plastic enclosure. Placing electrical components in a faraday-cage can reduce RE by bounding the emissions inside. Always remember to use EMI gasket to seal enclosures and properly ground the faraday-like enclosure. Filtering the inputs and outputs is always recommended. When filtering is not possible, the use of ferrites on cables is recommended. Ferrites can reduce the levels of electromagnetic fields because they can minimize the high frequency currents traveling along a cable. Adding a ferrite around a cable effectively makes a high resistance to a changing electromagnetic field, thus minimizing the changing fields around the cable and reducing the unwanted currents traveling along it.

When components are not designed with rigorous EMI considerations filtering should be implemented. Filtering techniques should be used early in the design stage. Filtering techniques are not typically practiced to save time and lower costs. Adding filters to the power lines of each component will limit the amount of conducted emissions along each power line. EMI filters at key points in the power system can dramatically decrease RE by isolating unwanted noise to particular components or regions in the vehicle. It is recommended to filter along known conducted emission paths, such as inputs and outputs of every known "noisy" component in the vehicle. As a good rule of thumb, filters should be used inside components where power is converted or transformed, such as in a DC to DC converter. Using filter will guide unwanted electromagnetic noise along a path to ground.

It is always important to follow the manufacturer's recommendations when installing equipment. Operating equipment out of its intended configuration and environment can compromise the systems' performance, thereby potentially cause malfunctions. To resolve these issues effectively, a fully integrated approach is required. System developers, vehicle integrators, RF propagation experts and modeling and simulation experts should collaborate to optimize the vehicles performance. User feedback is strongly recommended since they are ones who use the vehicles day to day and understand the operation and TTPs needed.

If the guidelines above are strictly followed our troops will have better communications performance in the field. Using an electromagnetically quiet vehicle will result in a significantly improved communications capability allowing a safer and more efficient mission completion.

References:

Tanya Busayadilok and Frank A. Bohn, GVSET Symposium (2009), Electromagnetic Compatibility of Tactical Vehicle's Sub-Systems and Communication Systems

DoD, MIL-HDBK-1857, 27 March 1998, HANDBOOK FOR GROUNDING, BONDING AND SHIELDING DESIGN PRACTICES