Electromagnetic Compatibility of Tactical Vehicle's Sub-Systems and Communication Systems

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ABSTRACT

This paper will discuss trends in compatibility issues between radio systems and Tactical Vehicle on-board systems which have been identified as potential interference sources and discuss electromagnetic compatibility (EMC) between co-located radio systems. All Tactical vehicles have electronic systems which come as part of the base vehicle, such as lights, air-conditioners, wind shield wipers, etc. all of which have the potential to disrupt communications. To further complicate the radio frequency environment today's tactical vehicles are being outfitted with new sophisticated technology such as programmable communications systems, sensor systems and remote weapon stations. The new systems are complex and are subject to emitting and absorbing electromagnetic radiation which can severely degrade radio system performance and cause inadvertent electromagnetic fratricide.

INTRODUCTION

Today's battlefield has significantly changed versus that which we faced 10 or 20 years ago. One of the constants through all this change is the fact that electrical and electronic systems still generate radiated emissions. These emissions are not necessarily desired emissions from a radio located on a platform but rather practically any electronic system which is operated where there is electricity flowing through the device. Electric motors cause small arcs of electricity between the rotor and stator, computers have clock frequencies, certain types of lights utilize an arc to cause gases to emit high intensity light. All of these and numerous more items cause both broadband and narrowband electromagnetic emissions which clutter the communications bands our tactical radios utilize. Fortunately there are certain military and commercial standards which help to identify and limit the allowable emissions generated from certain equipment. However when a piece of equipment is installed or used differently than the configuration it was tested in, it may act differently and generate emissions above those allowable limits.

Due to the rapid deployment of some vehicles and the variations within these vehicles, electromagnetic compatibility issues need to be assessed. Electromagnetic compatibility is the ability of the radio system to operate in its intended environment without causing interference to or suffering from other co-located systems. Systems on board a vehicle, such as an ignition system, can immensely affect the performance of tactical radios. Due to the nature of the systems and the performance of the radio, co-site interference is a considerable issue.

WHAT TYPES OF VEHICLES and SYSTEMS

Since the push started many years ago to make all the command and control decisions on the move, all the computers and tools which typically were on desk tops or co-located within a Tactical Operations Center (TOC) have now been integrated into all sorts of vehicles. Many versions of the vehicles have been produced. Each vehicle variant is dependent on the mission and the branch of the Department of Defense (DoD) using the vehicle. This difference also equates to variations of vehicular components and tactical radio systems integrated into each. Due to the difference in vehicles, the antenna placement on the vehicles differs as well. The table below lists several vehicles which have undergone electromagnetic interference (EMI) communications desensitization analysis.

Table 1: Table of vehicles tested for Communications Desensitization and some Tactical Communications integrated on the vehicle.

Vehicle	Blue Force Comms
HMMWV – M1114	PRC 119, VRC 104, VRC 103
HMMWV 1151	PRC 119, VRC 104, VRC 103
M1A2 Abrams Tank	PRC 119, VRC 103
LAV	PRC 119, VRC 103, BFT
Bradley Fighting vehicle	PRC 119, VRC 103
Hunter UAV	PRC-119, EPLRS
Shadow 200 UAV	PRC 119, EPLRS
MRAP Family of vehicles	PRC 119, VRC 104, PSC 5, VRC103, BFT
Assault Kitchen	PRC-119
Mobile Water Purification	PRC-119, BFT

DESENSITIZATION TEST

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 (an audio, BER (bit error rate) analyzer, or software) to the receive victim radio under test which measures the receive signal. A signal or bit generator is connected to a remote radio to generate a stream of data for the radio to transmit. The transmit radio connects to an antenna inside an anechoic chamber through a series of cables and variable and fixed 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)

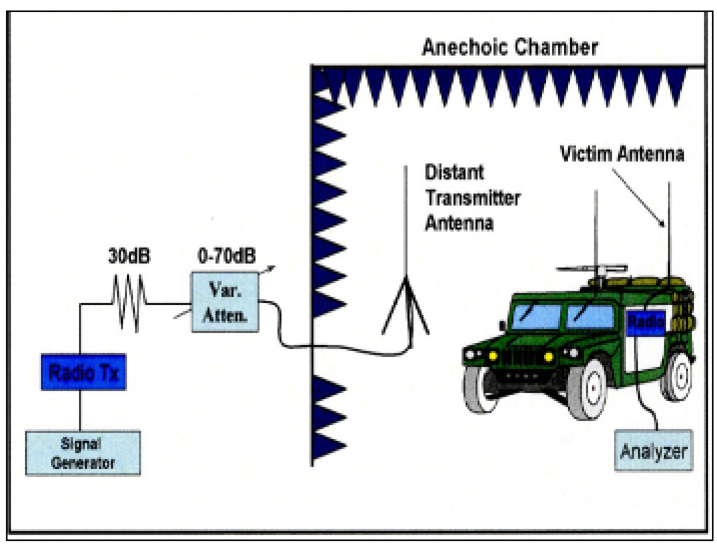

Figure 1: Basic setup for a desensitization test.

VEHICLUAR INTERFERENCE ISSUES

Analysis performed on a large number of vehicles revealed many of its major electrical systems caused various levels of EMI to communication systems. The master power switch and the engine are some examples of electrical systems that generate noise enough to interfere or degrade communications. As depicted in Figure 2 below, one particular vehicle showed approximately 10 dB of reduced sensitivity by turning on the vehicle's master power. The plot shows the difference between the ambient measurement, master power to the vehicle and when the vehicle's engine is turned on. The increase in noise due to turning the master power switch on is attributed to the distribution of power for turning on various electrical systems. When the engine is energized it is hard to tell which newly energized system is generating RF noise. It could be attributed to the alternator/generator or even the computer system which monitors the vital functions of the engine. There are many contributing factors.

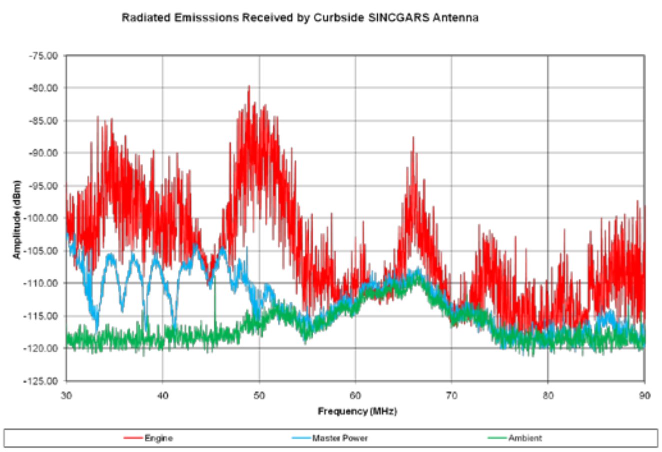

Figure 2: Comparison chart of RF emissions generated within the SINCGARS frequency band by simply starting the vehicle.

Other vehicle components cause the radios to degrade. Some of the worst culprits being the air conditioner, halogen or mercury vapor spot lights, and surprisingly, the windshield wipers. Using the example of the windshield wipers, desensitization at the radios is not consistent throughout different types of vehicles. In the following diagram, a variety of vehicles are shown with the degradation the wipers caused across the different radios. Notice that the different vehicles' wipers are causing different amounts of degradation across different bands. Several vehicles did not have all the same radios and the antennas were mounted in various locations, which drive the variations in the chart below.

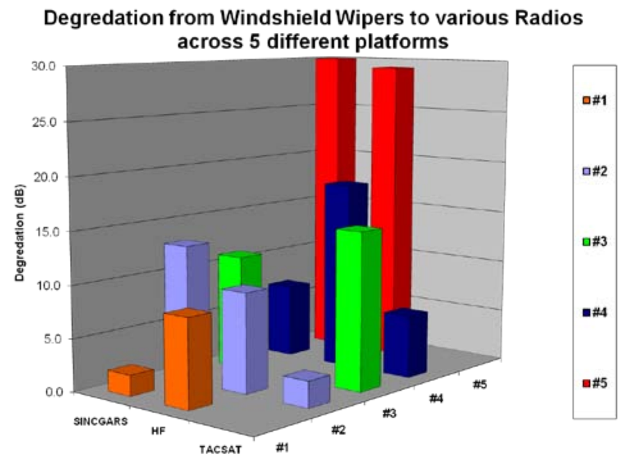

Figure 3: Comparison chart of degradation caused by windshield wipers.

Another issue apparent on the vehicles is co-site interference between tactical radios. Vehicle communication suites generally consisted of Blue Force Tracking (BFT), HF (high frequency), SINCGARS (single channel ground to air radio system), and a TACSAT (tactical satellite) or EPLRS radio. Despite the frequency separation between various types of radios, electromagnetic compatibility (EMC) issues may arise while simultaneously operating radios on a co-located platform. One widely known co-site issue is interference caused by harmonics that are generated by radios operating in a lower frequency than the victim radio. However, high power signals received from a radio also had the capability of reducing sensitivity to another co-site radio.

This was found to occur regardless of the considerable frequency difference between transmit and receive frequencies of the co-located radios. In one particular case, a TACSAT radio showed that at particular frequencies being radiated by an HF radio, a fault message would be triggered on the TACSAT radio, in particular the VRC-l03, display panel indicating a high power signal received by the external PA (power amplifier) causing the radio to switch into a protected mode. The following graph shows an example of the harmonics that are being generated by a particular HF radio and is being picked up by the SINCGARS radio. It is a prime example of how harmonics are received at the receiver end.

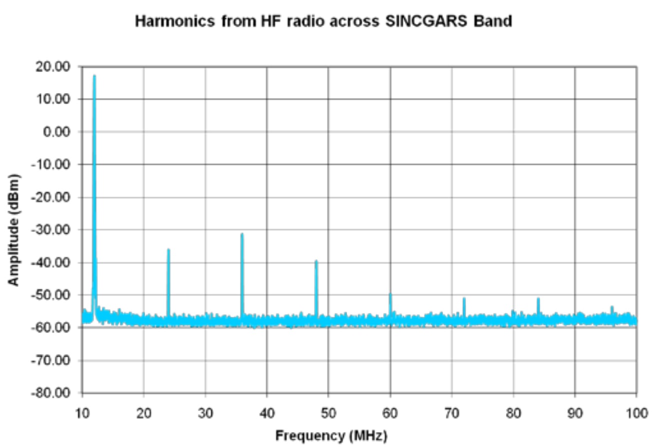

Figure 4: Harmonics seen by the SINCGARS antenna emanating from the HF radio.

SOLUTIONS

Various methods can be utilized to minimize the overall affect of RF emissions as generated by the vehicles and integrated (non-transmitting) equipment. Some of which may include proper connectors, cables, and cable placement and wiring. To further reduce the amount of electromagnetic interference, bulkhead connectors could be implemented to minimize the noisy currents from traveling along the cable and outside the vehicle to where it can couple into the antennas. Also, reducing the grounding and bonding impedance of installed equipment to allow better connection will reduce unwanted currents from flowing along surfaces and cables. The effects of coupling have been observed in many vehicles where unwanted signals travel from one component to the other via travelling along the outer shell of the cable. If the cable is not well shielded, the signal can pass easily into the center conductor of the cable and pass right into the system. The use of ferrites along cables has shown to minimize this effect.

Many systems on vehicles cause degradation to the overall performance of the blue force communications. Some systems on the vehicles contain multiple subsystems. Some vehicular systems that show detrimental effects are caused by the master power and the engine. Further investigation into these systems may determine the cause of the elevated noise floor when energized, and a solution may be determined once the cause is identified. Another cause for interference could be due to coupling signals along radio frequency cables or power lines. By ensuring that power lines are not placed in parallel alongside RF cables, signals coupling along wires may be reduced, increasing radio performance.

Some radio systems interfere with each other and interference mitigation is needed to increase the performance. One way to maximize performance is through the use of filtering. Filtering on the radio front end can alleviate noise generated by that particular radio and keep unwanted emissions from interfering with other receivers. Filters on the radio front end can also minimize or eliminate high power emissions from other out of band transmitters and keep those signals from desensitizing your receiver.
Antenna placement significantly affects the performance of communications. There may be some limitations on where antennas can be placed. For example antennas cannot be placed where it obstructs the field of view of the driver

It can also not be placed where it will obstruct the movement of a turret or in the vicinity where a gunner, driver or commander would be exposed to high levels of radiation from the antenna. The remaining amount of space on board the vehicle may be limited; however by finding optimal isolation between the multiple radio systems' antennas, the quality of the communications can be maximized. Since a trial and error method is time consuming, antenna modeling and simulation is recommended to find optimal placement of antennas.

To effectively resolve all the issues with communications systems, a fully integrated approach is required. System developers, vehicle integrators, RF propagation experts, antenna design experts, and antenna modeling and simulation experts should collaborate to optimize the vehicle as a system. Not only should technical expertise collaborate, but also the war fighters who will use the vehicle.

Currently there are many vehicles and sub-systems that create electromagnetic noise and degrade communications. There are also many vehicle integrators which have developed teams to address these issues and have taken already fielded vehicles and brought them into an EMI chamber and performed vehicular quieting efforts. One of the issues being addressed in one of my programs is the alternator. Integrators are now looking into new alternators that produce lower amounts of RF to outfit the vehicles. Another issue being investigated is the side spot lights. Integrators are looking into using LED lights versus the traditional halogen bulbs that are currently on vehicles. These lights have been proven to reduce the radiated emissions as well as reduce the power required to run them.

To address topside issues, or compatibility between radio transmitters or even between jammers and radios, a thorough evaluation of antenna placement is needed. RF modeling and simulation is a very good and economical approach to determine antenna placement if there is a concern on antenna patterns and the coupling between antennas.

Antenna modeling and simulation is being assessed on many newer tactical vehicles to assure proper operation and coverage of the jammer systems. Currently, CERDEC is routinely providing integrators from both the Army and Navy with topside antenna model patterns to show the most effective antenna placement.

Although many advances have been made in reducing emissions on platforms, the approach that many integrators take is to design a vehicle with a rack and stack mentality, so they can get all the widgets the commanders want on them, with little or no regard for electromagnetic interference. The first time they start to worry about interference is when the soldiers in the field complain about not being able to communicate and they find that the vehicle systems are causing the issues.