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Effects of Electromagnetic Pulse on EFI / EURO Compliance Vehicles

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***Abstract—* Electromagnetic Pulse (EMP) has the potential to be used as a weapon to jam / stall the electronic equipment. A determined adversary can achieve an EMP attack capability without having a high level of sophistication. EMP weapons have the capability to produce significant damage to critical electronic infrastructures. The vulnerability to EMP attack is increasing as the dependence on electronics continues to grow. The current vulnerability of critical infrastructures in Pakistan is critical; however, countermeasures are feasible and well within the nation's means and technological resources.**

I. INTRODUCTION

Electromagnetic pulse can interfere with electronic systems of EFI vehicles and can stall these vehicles. Radio frequency (RF) energy coupled into the electronic circuits of the vehicle can interfere with the operation of the electronic control unit (ECU), which is critical to the performance of modern internal combustion engines. Severe disruption of the ECU can result in the engine stalling and consequently prevent re-ignition. Such RF-based techniques for disabling or immobilising vehicles have been reported in literature [1-3], though specific and detailed test data is rare.

II. TYPES OF EMP WEAPONS

There are several ways from which electromagnetic pulse can be triggered, e.g. through detonation of a nuclear weapon and by the Compton Effect. As the nuclear device is being detonated, intense electromagnetic energy is released which in turn interacts with the atoms in the Earth's atmosphere that become ionized. The electrons released during the ionization are then picked up by the Earth's powerful magnetic field, thus creating a fluctuating electric current that generates a magnetic field and an electromagnetic pulse is created. Following are some examples of EMP weapons:

A. Directed Energy Weapons

Directed energy is an umbrella term covering technologies that relate to the production of a beam of concentrated electromagnetic energy or atomic or subatomic particles. A directed-energy weapon (DEW) emits energy in an aimed direction without the means of a projectile and intended effects may be non-lethal or lethal, e.g. destruction of enemy's equipment, or controlling crowd. Some of these weapons are in active use while others under active research and development. In science fiction, these weapons are sometimes known as death rays or ray guns and are usually portrayed as projecting energy at a person or object to kill or destroy. Many modern examples of science fiction have more specific names for direct energy weapons due to research advances. The energy can come in various forms:

- Electromagnetic radiation, lasers or masers
- Heat
- Particles with mass, inch particle beam weapons
- Flamethrowers
- Sound, inch sonic weapon

B. EMP Bombs and Nuclear Detonation

An electromagnetic pulse bomb is a weapon destined to destroy the electric and electronic infrastructure of a particular target. Considering the fact that electricity powers almost every device currently used around the world, it's not hard to imagine the kind of panic the detonation of an electromagnetic pulse bomb would trigger.

C. EMP Canons

A device has been developed as prototype to interfere with and stall EFI cars. The idea is that an electromagnetic pulse would be used to disable a car's microprocessors, chips, and other electronics. For example, the EMP 'cannon 'developed by Eureka Aerospace, weighs about 50 pounds and can stop cars in their tracks from a distance of 200 meter.

III. SUSCEPTIBILITY OF EFI VEHICLE ENGINES

In general terms, coupling of high power RF energy into an electronic system may result in the following effects on electronic systems:

- Temporary interference to normal operating conditions for the duration of illumination, e.g.

blanking of video outputs, increased bit error data rates.

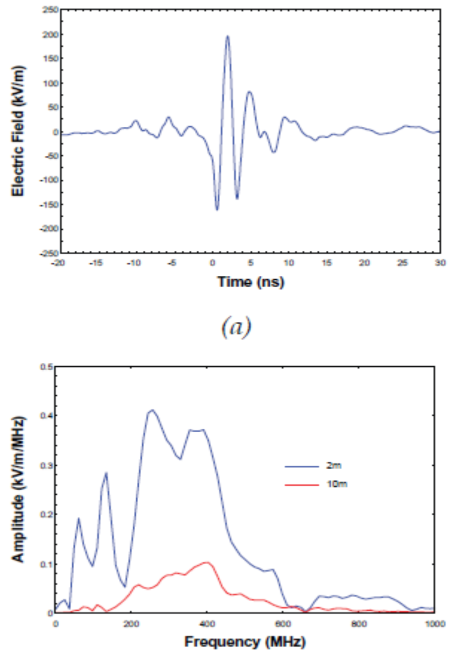
- Upset or disruption to normal operating states that continues post illumination, requiring manual reset, e.g. latch-up of digital circuits.
- Physical damage to sensitive components.

The exact response will depend on the power level and other characteristics of the RF pulses and of course the composition and configuration of the electronic system as well as the type and level of electrical shielding. The majority of modern cars are fitted with an Electronic Fuel Injection (EFI) system in order to provide improved power efficiency for better fuel economy and cleaner emissions. Central to an EFI system is the Engine Control Unit (ECU), alternatively known as Engine Control Module (ECM). The ECU is an electronic device used in an internal combustion engine that controls various aspects of the engine such as fuel usage and ignition timing. It takes inputs from various sensors located throughout the engine and manages the engine performance. The ECU must conform to fairly high standards of electromagnetic compatibility. Most often the ECU is housed within a metallic shielded enclosure and filter components are used to suppress RF interference. In addition, computational algorithms can be configured to further minimise functional errors. Given that there are physical and economic limitations to the degree of electrical shielding that can be provided to the entire wiring circuit, the extent of measures are usually based on RF field levels that are found in a normal operating environment. Intentional illumination of a vehicle by an external RF source of high intensity can induce currents and voltages at a level that might cause significant disruption of engine operation. In one scenario, the ECU itself might operate correctly but the input signals from various sensors are corrupted to such an extent that the ECU response is inappropriate, particularly with regard to injector and ignition timing. The engine operation could then be impaired temporarily, exhibiting rough operation and eventually stall by a possible accumulative effect from a burst of radiated pulses. Incorrect operation of the ECU occurs from a direct upset to an internal microprocessor and hence prevents correct engine operation. In these events the engine might stall instantly and require manual intervention to restart, providing the ECU is not damaged.

IV. TESTS CONDUCTED BY DEFENCE SCIENCE AND TECHNOLOGY ORGANIZATION (DSTO), AUSTRALIA

Commercial EMP systems [1-3] that might be used for engine stopping are not generally available for evaluation. Therefore, recent engine stopping tests at DSTO took advantage of an on loan system provided by Diehl BGT Defence. This system utilises a high-voltage Marx generator to produce pulses that resonantly excite two broadband dipole antennas. Field measurements of the radiated output from the HPEM source were made by DSTO using Ddot field probes (Prodyn AD-70) connected to a digitising sampling oscilloscope (Tektronix TDS784C) via fibre optic links (PPM FOLNET). Figure 1 shows the measured field at a range of 2m and the corresponding amplitude spectrum calculated using a numerical fast Fourier transform. The magnitudes, and spectral range, of the measurements were consistent with expected system performance.

All the vehicle tests and measurements were conducted in an open test area at the DSTO High Power Microwave Test Facility, South Australia. The tests were performed under static conditions with the HPEM source always at a fixed point and the vehicles under test (VUT) parked at selected distances and aspects relative to it. The vehicle would then not be moved until after the test run. A typical test setup is depicted in Figure 2. Eight different vehicles were tested. All manufactured from 2003-05, including one example with a hybrid electric/fuel engine.



(b)

Figure 1: (a) Electric field measurement at 2m along the main radiated beam and (b) radiated spectra corresponding to measurements at distances of 2m and 10m.

Figure 2: Image showing typical test set-up.

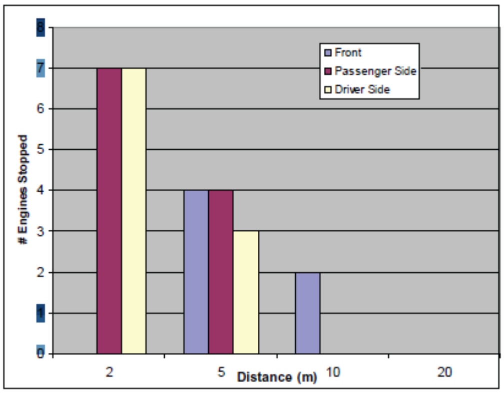


Figure 3: Graph indicating general effective distance for stopping vehicle engines.

VI. RESULTS AND DISCUSSIONS

A. *Effective Distance*

The effectiveness of the EMP system with distance is summarised in the graph shown in Figure 3. The histogram levels indicate the number of different vehicle engines that were able to be stopped, in at least one test run, at the given distance and orientation. It is clear that the system is most effective when it is within 5m of the target vehicle, as this is where the majority of vehicle engines were able to be stopped. This included the hybrid engine, which was able to be stopped in both fuel and battery modes of operation. The peak field strengths in this effective region are greater than 50 kV/m.

B. *Influence of Exposure Time*

The importance of the EMP burst duration, or exposure time, in determining the level of effect was also investigated. The results clearly indicate that the exposure time required to ensure engine failure varies significantly between vehicle models. One engine, for example, could be consistently stopped with relatively short bursts of less than one second duration, whilst for other vehicles several seconds were necessary before the engine completely stalled. In some test runs it was observed that engines near stalling point would sometimes recover if the exposure time was of insufficient duration. This was particularly noticeable with one vehicle when tested at elevated engine speeds (2500 rpm).

C. *Influence of Vehicle Orientation and Engine Speed*

Other parameters such as vehicle orientation and engine speed were also studied during the test. Overall the results suggest that the engines could be slightly harder to stop as the speed increases. For most vehicles the variation in response with orientation appears to be minor when in such close proximity to the source.

VII. SUMMARIES

Overall the test results achieved with the Diehl HPEM system can be summarised in the following points;

- The EMP system did exhibit a generic capability for remotely stopping car engines, including a hybrid engine.
- The most effective distance was within 5m, which corresponds to incident field strengths in excess of 50kV/m (peak).
- An exposure time of several seconds is generally required to ensure complete effectiveness. It is possible that an increase in the pulse repetition frequency (PRF) might provide some improvement in system effectiveness; however, this would require a corresponding increase in the average input power requirement from the primary power supply.

RF vulnerability studies of electronic engine control systems at microwave frequencies will also be considered in future. At these frequencies a more directional antenna system with potentially longer stand-off capability could be a more viable option.

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