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EFFECTS RESEARCH TEST REPORT FOR THE NATIONAL INSTITUTE OF JUSTICE (NIJ) ENGINE STOPPER PROGRAM

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Final Report

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FORWARD

This report covers the data acquisition, processing, analysis efforts and results of the Radio Frequency field tests performed from 22 to 29 April 2009 at the Mobility Assessment Test and Integration Center (MATIC) facility on the Laguna Pueblo Indian Reservation in Laguna, New Mexico. The test articles evaluated during the tests consisted of automobiles provided by the Air Force Research Laboratory (AFRL).

The main objective of the tests described in this report was to ascertain the effectiveness of the prototype engine stopper Radio Frequency (RF) source to stop vehicles under simulated chase scenarios. Complementary objectives consisted of obtaining antenna beam mapping information and determining the RF environment inside the automobiles to determine compliance with Permissible Exposure Levels (PELs.)

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ACRONYMS AND ABBREVIATIONS

AFRL	Air Force Research Laboratory
AM	Amplitude Modulation
CONOPS	Concept of Operations scenarios
EM	Electromagnetics
EMWS	Electromagnetic Weapon System
ERP	Effective Radiated Power
FM	Frequency Modulation
HPM	High Power Microwaves
KAFB	Kirtland Air Force Base
MATIC	Mobility Assessment Test and Integration Center
NIJ	National Institute of Justice
NM	New Mexico
PEL	Personnel Exposure Levels
PRF	Pulse Repetition Frequency
PW	Pulse Width
PWM	Pulse Width Modulation
RF	Radio Frequency
USDOJ	United States Department of Justice

EXECUTIVE SUMMARY

During the month of April of 2009, Fiore Industries Inc. conducted a series of RF susceptibility tests on automobiles under idle and dynamic conditions. The test activities described herein consisted of determining the Electromagnetic (EM) characteristics of the Fiore brassboard RF source and the response of automobiles to that RF source in simulated Concept of Operations (CONOPS) scenarios. The purpose of the tests was to demonstrate the feasibility of the RF source as a non-lethal engine stopping weapon.

The test articles consisted of several AFRL test automobiles. The brassboard Fiore source named herein as the Electromagnetic Weapon System (EMWS) was developed to overcome range to power proportionality problems associated with current EM engine stopping systems and it is based on past engine stopping effects testing. The EMWS version employed for the demonstration tests described herein is a brassboard system. A follow on program would concentrate on developing a prototype systems including antenna that is more compact, thus better suited for integration onto a typical pursuit vehicles.

The brassboard EMWS consists of multiple pulse amplifiers routed individually to their respective antenna elements. The system is capable of generating 2.4KW, 30μsec pulse width and 8 KHz Pulse Repetition Frequency (PRF). The fields are launched via an antenna composed of 24 elements with a total gain of 23 dB. The system is remote controlled and is powered from two deep-cycle lead acid batteries. For the demonstration tests the entire system was securely mounted on a flatbed Ford F350 pick-up for chase operation.

The test series started with the evaluation of the antenna beam patterns, followed by electric field measurements both in and out of test asset ─ understanding of the RF environment inside the vehicles' occupant area allows the determination of the RF limits and its relationship with the RF PELs. For the PEL measurements, an open ended waveguide sensor was placed inside the vehicle in the area where the head of the driver on the target vehicle would be located. The power density levels measured at that location was compared to the predicted PEL. This comparison shows that the EM environment produced by the EMWS when used to stop vehicles will not exceed the PELs and therefore it will not harm the occupants of the targeted vehicles.

After the above mentioned activities were complete, the automobile susceptibility evaluation began; the 1st phase of the susceptibility testing was performed with the vehicles under idle and dynamic conditions. The deleterious effects observed during the idle portion of the tests consisted of engine disruption (engine stumbling) at 70 ft, and the engine was stopped (engine cannot re-start while the RF source is on) at 60 ft, 50 ft, 30 ft when the vehicle was illuminated from the front, driver side and passenger side respectively. The 2nd phase of the susceptibility testing was performed with the vehicles under dynamic conditions and staged chase scenarios at speeds of up to 30 miles per hour yield similar results, the engine of the Plymouth Voyager was stopped at distances of 60 ft, 40 ft, and 20 ft when illuminated from the front, driver and passenger/rear sides respectively and at various speeds.

The successful results of the tests demonstrate that although the EMWS can be successfully employed against automobiles, it will need to be refined for it to be effective with a much larger automobile sample size. RF source upgrades, prototype development and demonstrations would be carried out as follow on activities, if funded.

In this report, Chapter 1 provides introductory and background information for the tests, Chapters 2 and 3 provide a detailed description of the tests and the test results, respectively.

1.0 INTRODUCTION

1.1 GENERAL

The United States Department of Justice (USDOJ)-NIJ is assessing the potential of High Power Microwave (HPM) technology to safely and effectively immobilize commercial motor vehicles in the United States. This requires stopping vehicles without irreparable effects to the engine electronics and without adverse effects to any critical human life or comfort electronics (pace makers, hearing aids, etc.). As part of a contract with the NIJ, Fiore Industries conducted a two phase test series at the Laguna Industries outdoor test facility in April 2009 to evaluate the effectiveness of a newly developed RF source – a brasboard RF source designed to produce effective peak and modulation schemes for disabling. Phase I characterized the EM properties of the EMWS source (power generation/antenna), and Phase II evaluated the effectiveness of the source against automobiles under idle and simulated CONOPS scenarios. The results of these evaluations provide the basis for the development of an RF source prototype and testing of a viable non-lethal RF weapon capability to stop vehicles. It shall be noted that the test activities described herein were conducted not to completely define all modes and mechanisms of vehicle engine stopping effects, but rather to demonstrate the effectiveness of source waveform modulations.

This test report describes the test procedures and the outcome of the tests. In addition to the source parameter (peak power, modulation, attack aspects, etc), audio and video was also recorded to further document the results.

The test activities and their outcome as described in this report is a continuation of a test series designed to evaluate the effectiveness of the brasboard RF source with an efficient waveform modulation as a potential engine stopping tool. Phase I focused on establishing baseline RF waveform characteristics (i.e., carrier frequencies, PRF and Pulse Width (PW)) for which engine stopping sources could be developed. The data gathered during Phase I automobile evaluations was used to design the brasboard RF source used during the outdoor demonstrations at Laguna's outdoor test range.

1.2 PURPOSE

The purpose of the test activities described herein was: (1) Measure the RF characteristics of the RF source, (2) verify that driver exposure limits are below PEL, and (3) evaluate the effectiveness of the RF source against driven vehicles under a simulated CONOPS scenario. The free-field tests concentrated on the power and PRF most effective for upsetting the automobile electronics.

1.2.1 Source RF Characteristics

- Exit Criteria: Measured free-field levels at test locations specified in beam maps
- Performance Criteria: Antenna transmitted measured field levels consistent with calculated field strengths with reasonable repeatability
- Final Data Product /Data Requirements:
  - Field Range Measurements
  - 10' x 6' Beam Map taken along the anticipated driving centerline; with field probe measurements taken at 1' intervals both vertically and horizontally

- Test Methodology: To understand the field intensity impinging upon the test asset, an understanding of the source Effective Radiated Power (ERP) and beam pattern is needed. By measuring the field strength at various locations in and around the beam axis, a beam pattern was identified and later used for aiming the antenna.
- Expected Results: RF source beam pattern identified antenna coverage areas and electric field levels as a function of range in both E and H axis planes.

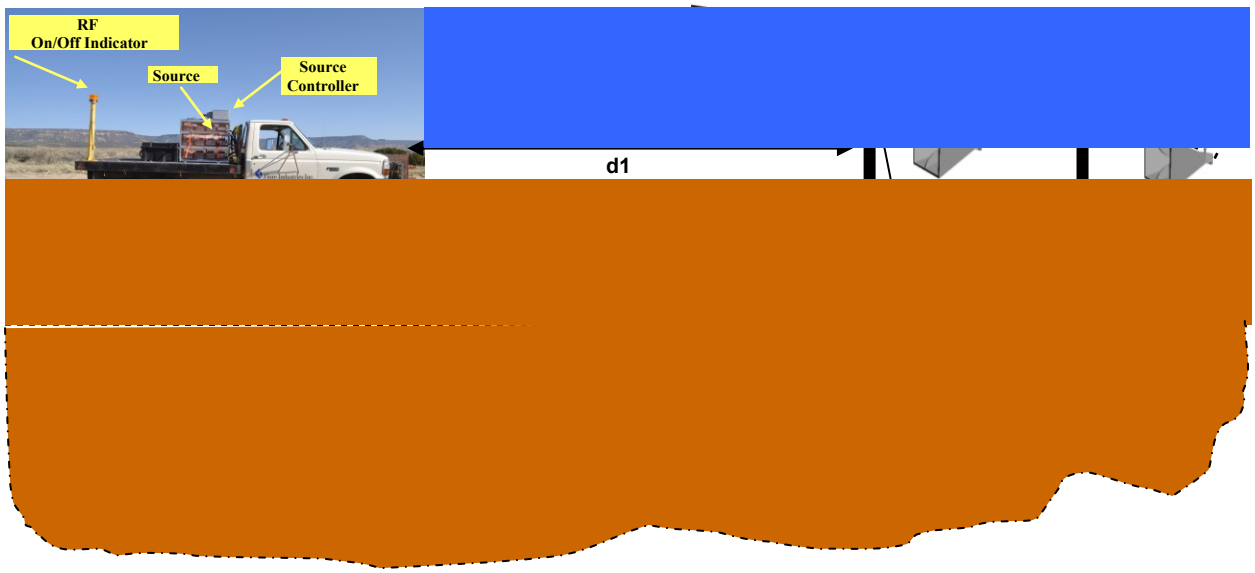

Figure 1-1: Brasboard RF Source field map set-up

1.2.2 Verify Driver Exposure Limits Are Below PELs

- Exit Criteria: Knowledge of maximum measured field levels within test assets.
- Performance Criteria: EMWS creates < 0.12.8mW/cm^2 field levels within test asset.
- Final Data Product / Data Requirements: Electric Field levels in test asset are within allowable PELs.
- Test Methodology: In order to verify the safety and potential use of the EMWS system as a non-lethal engine stopper weapon, its field strengths within the test assets must be quantified. Those measured values are then compared to the accepted PELs for determination as to the safety of those exposed to the RF field generated by EMWS.
- Expected Results: Measured electric fields at driver's locations are below PELs.

1.2.3 Evaluate potential for EMWS as a non-lethal engine stopper weapon

- Exit Criteria: Test assets have been tested and effects data recorded.
- Performance Criteria: EMWS performance evaluation based on the test assets disruption and level of disruption.
- Final Data Product / Data Requirements: Final Data Products include:

- Video documentation of test asset under evaluation
- Test parameters for each test run, to include changes in driver input operation as well as changes in source configuration
- If applicable, any necessary test asset repairs as a result of induced RF effects

- Test Methodology: In order to validate the results of testing performed under section 1.2.2 and evaluate the potential of EMWS as a viable engine stopper system, the testing was performed using a simulated CONOPS. An analysis of the recorded data provides information of automobiles affected by EMWS and the duration of effect.
- Expected Results: EMWS replicates frequency sweep tests (Phase I of Engine Stopper program) at anticipated automobile effect settings and test setup configurations.

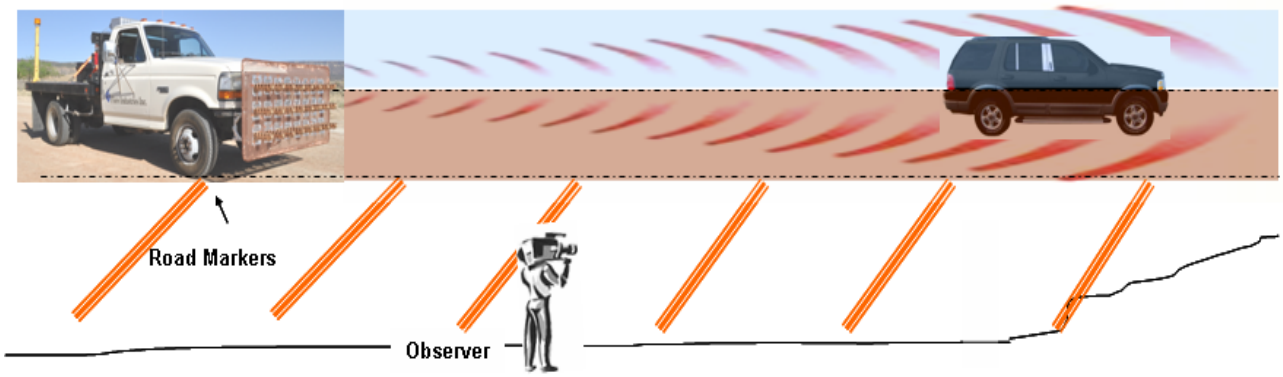

Figure 1-2: Typical test scenario