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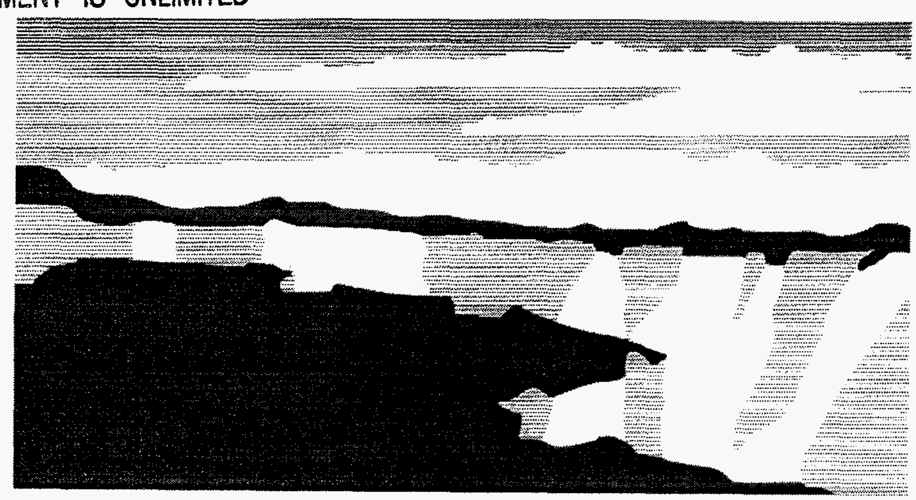

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Electromagnetic Targeting of Guns

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Abstract

This is the final report of a one-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). Electromagnetic pulse (EMP) signals produced from explosives being fired have been reported in the literature for fifty years. When a gun is fired it produces an EMP muzzle blast signal. The strength and nature of these signals was first analyzed in the early 1970s, while the results were interesting, no follow-up studies were conducted. With modern detection and signal processing technology, we believe that these signals could be used to instantaneously locate guns of virtually all calibers as they fire. The objective of our one-year project was to establish the basic nature of these signals and their utility in the concept of electromagnetic targeting of guns.

1. Background and Research Objectives

Radio frequency (rf) signals produced from the detonation of energetic materials have been reported in the scientific literature for the last fifty years. When a gun is fired, it produces a burst of rf noise as the bullet exits the muzzle. The research objective of our one-year LDRD project was to establish the existence and nature of rf emissions from the firing of a variety of weapons to include rockets, rifles, and heavy guns. The eventual goal is to establish the possibility of using these signals to allow speed-of-light detection and location of weapons that operate by the use of energetic materials. We collected data from a wide variety of sources to maximize the amount of data produced and the number of potential applications.

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2. Importance to LANL's Science and Technology Base and National R&D Needs

The DoD's Advanced Research Projects Agency (ARPA) has expressed interest in this technology as a potential anti-sniper system. The British Ministry of Defense has also expressed interest in conducting joint research in this area. The US Army's Missile Command has signed a Memorandum of Understanding with the Laboratory to facilitate some of our rocket measurements at their facilities.

3. Scienctific Approach and Results to Date

The technical approach was to field a variety of antennas and monitors around the firing weapon and then record these signals on digital scopes. In each case, the gun or rocket motor was remotely fired at a firing site while the data collection equipment and operators were located nearby in an underground bunker. The antennas deployed consisted of a suite of dipoles, monopoles with ground planes, bicone antennas, and electric field monitors. Location of the sensors from the weapon were varied in both azimuth and distance as well as polarity. Data collection usually occurred at a 8-10 shot-per-day rate and lasted one or two days.

The type of rf noise signal we were seeking had a normal duration of nanoseconds to microseconds during a firing event that lasted from 4 milliseconds to 4 seconds. This great difference in time scales created a very difficult situation in which the proper triggering of the scopes was critical to the collection of any meaningful data. In none of the cases was it possible to trigger directly from the rf signal. This was due to the high rf background noise of the area coupling into antennas that were of necessity very broad band in nature. Triggering of the scopes was accomplished by various methods including infrared detectors, light screens, coupling loops, and foil switches at the muzzle. Many of these interfered with the actual signal that was sought and at least partially corrupted the data. To overcome this problem a technique was developed that used the barrel of the weapon as one leg of a dipole antenna. This appeared to give the most reliable and usable signal for both triggering of scopes and collection of data. Experiments have been conducted on military rifles, experimental cannons (both 30-mm and 60-mm.), and antitank rockets. We also planned to collect data on tank guns (105-mm and 120-mm) and a 203-mm howitzer. To gain a greater physical understanding of the mechanisms involved, longer records were generally taken for completeness. This meant the loss of some of the high frequency information but was necessary at this early phase of experimentation and theory.

A military rifle was employed for a number of experiments. Initially problems developed with the grounding of the rifle barrel to a metal support structure, but once isolation was achieved consistent data was collected. The barrel of the rifle was used as half of a dipole antenna. This was accomplished by connecting the center conductor of a coax cable to the rear of the barrel while stripping back an equal length of ground strap. The signal captured (Figure 1) is representative of many shots taken in this configuration. Both traces are of the same signal only recorded with different amplitude settings. Initially there is a sharp voltage drop that occurs in 10 to 50 microseconds followed by a return to near zero over the next millisecond. The signal then takes a rather dramatic drop to about four times that of the initial one. The scope was triggered by the signal. On some records there are occasional spikes of short duration that occur out to six milliseconds. This type of signal suggests that there are more than one phenomenon in operation; a long term one that operates on a hydrodynamic time scale (milliseconds) and another that operates on a characteristic electronic scale of microseconds. These are probably associated with charged molecular fragments or electrons free to move in a plasma.

A later experiment with a 30-mm cannon is shown in Figure 2. Again the barrel is half of a dipole antenna, but in this case the barrel is now some three meters long. The trigger for the scope is provided by a copper foil switch placed over the muzzle. This switch was pierced by the nose of the projectile at the zero point of the record. What is particularly interesting in this series of shots is that signals were recorded before the projectile exited the barrel. This may imply that part of the propellant gas products have actually escaped past the projectile and are giving an early signal. This is immediately followed by a dramatic signal of the opposite polarity immediately after the projectile exit. In all cases there is a large positive signal about 2.0 seconds later. It can be easily seen on this record that all of these signals are much above the ambient background.

A data collection team was dispatched to the US Army Missile Command testing facility to observe a series of anti-tank rocket motor tests. These were conducted as static tests and measurements were taken with a multi-gain electric field change meter. Thrust data was also recorded. The rocket plume contains combustion by-products containing nitrogen and oxygen ions. These charged particles produce a measurable electric field as they leave the rocket nozzle. This creates a changing electric field until the plume reaches electrostatic equilibrium. Electric field activity was also noted anytime there was a change in thrust. Figure 3 shows the thrust (bottom curve) and the electric field (top curve) on the same time scale. Examination of the two signals demonstrates a correlation between thrust and electric field changes. During this particular test the rocket underwent a catastrophic failure at about 2.2 seconds into the burn. This can be seen by the fact that the thrust goes off scale and the electric field undergoes an abrupt change. All of the data from these experiments show a direct correlation between the rate of change of thrust and the measured electric field. Remote sensing of thrust performance appears possible through the observation of this phenomenon.

A large quantity of data has now been collected under this project and our initial understanding of its meaning is at best somewhat murky. There are both rf and field emission from all these events and at this time it appears that the field changes are the most reproducible and consistent. It remains to be seen if a sufficiently sensitive detector could be made to sense these field changes at a useful distance.

The major result from our data collection is that we have found signals present in every weapon that has been tested; from rifle to cannon to rocket motor. In many cases there have been significant electric field changes that have not resulted in measurable rf noise emission. This fact may be a result of our desire not to miss any of the signal at the expense of a loss of fidelity at the higher frequencies. The rf signals have proven less repeatable on a shot-to-shot basis. These rf signals appear to be caused by arcs that develop in the propellant cloud while the electric field changes are repeatable and associated with the evolution of the gas cloud at the exit of the barrel or nozzle.

Our conclusion at this time is that this phenomenon is present in a wide variety of weapons systems and that there are multiple mechanisms combining to produce these results. The high frequency signals appear to be less useful than originally thought but the electric field changes may prove useful for both detection and diagnostics.

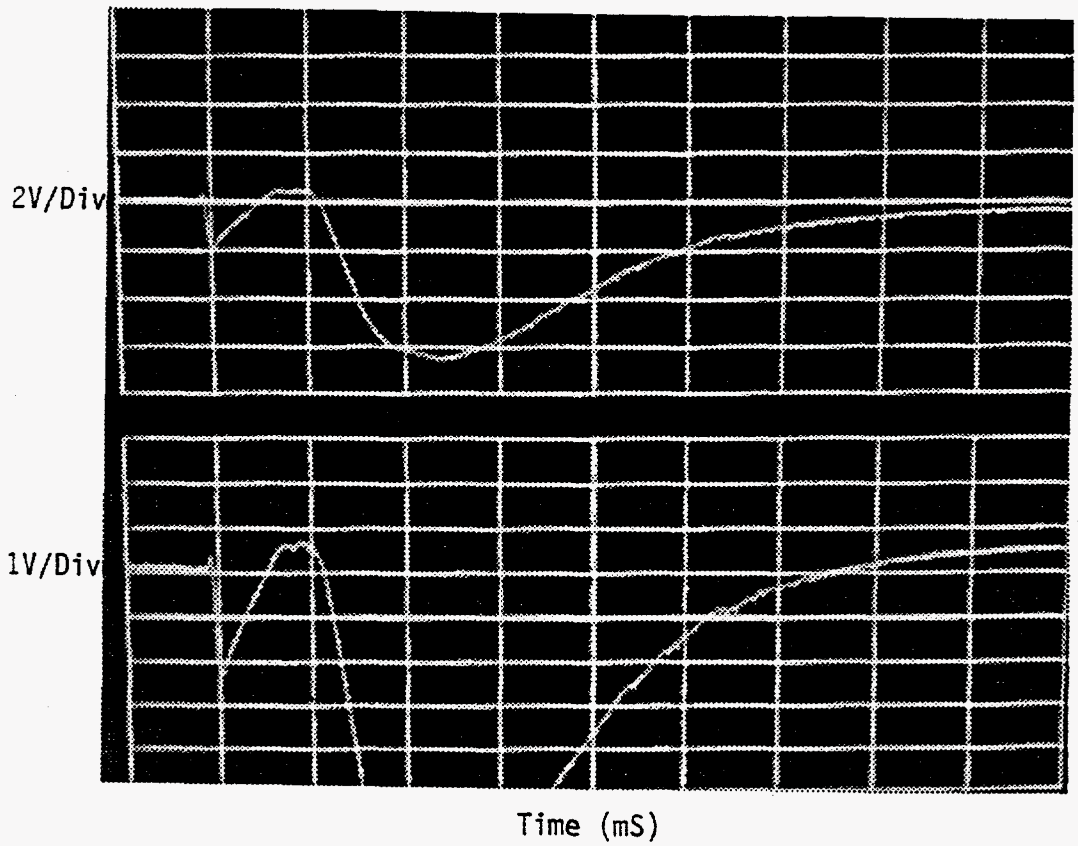

Figure 1. This is is the signal from the firing of a military rifle. Both traces are the same signal but recorded at different amplitudes.

SHOT #4 COAX ANTENNA ON BARREL

LANL DAAAC / Voss Scientific

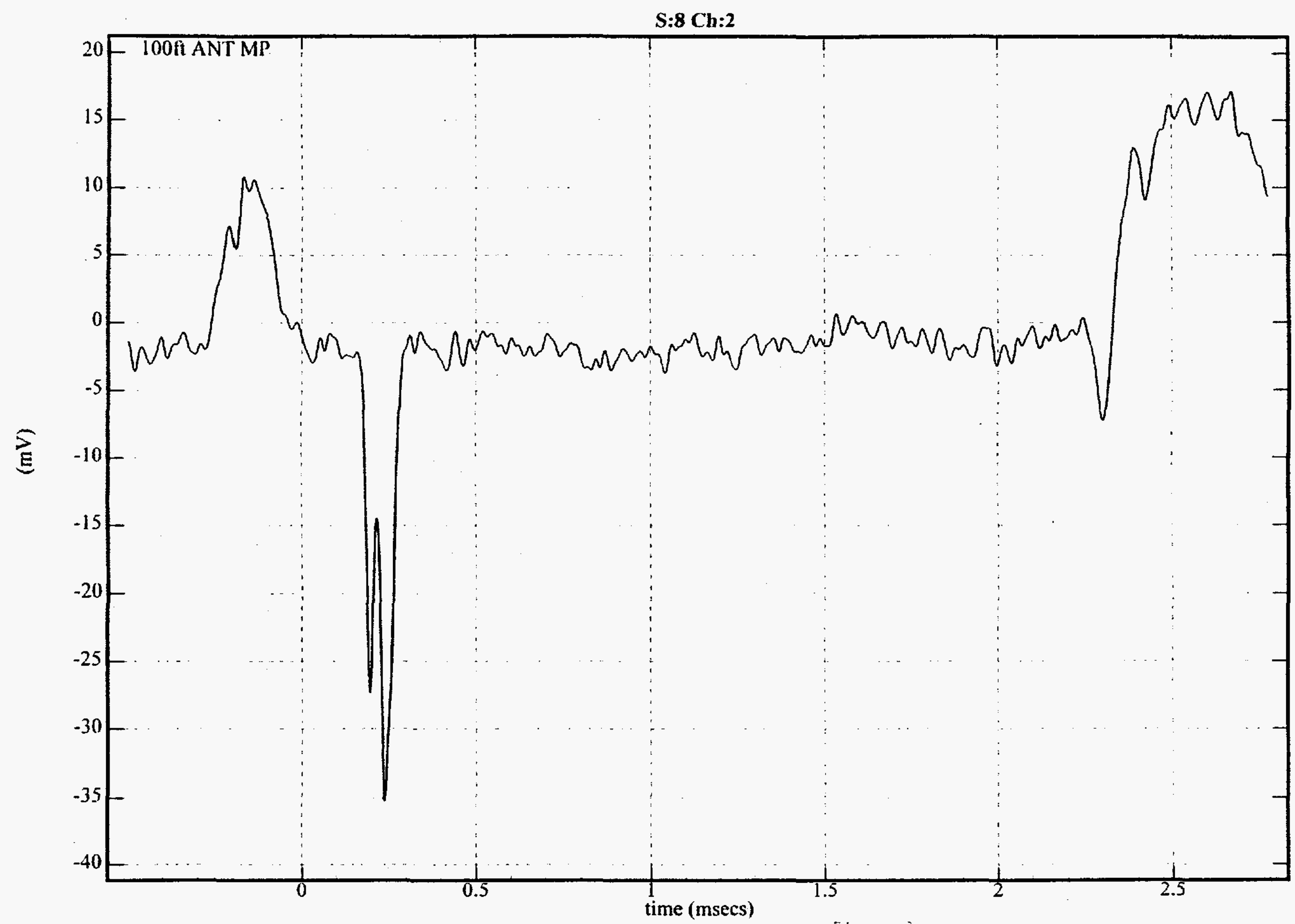

Figure 2. Signal from 30-mm experimental cannon. Zero time is bullet exit from the muzzle.

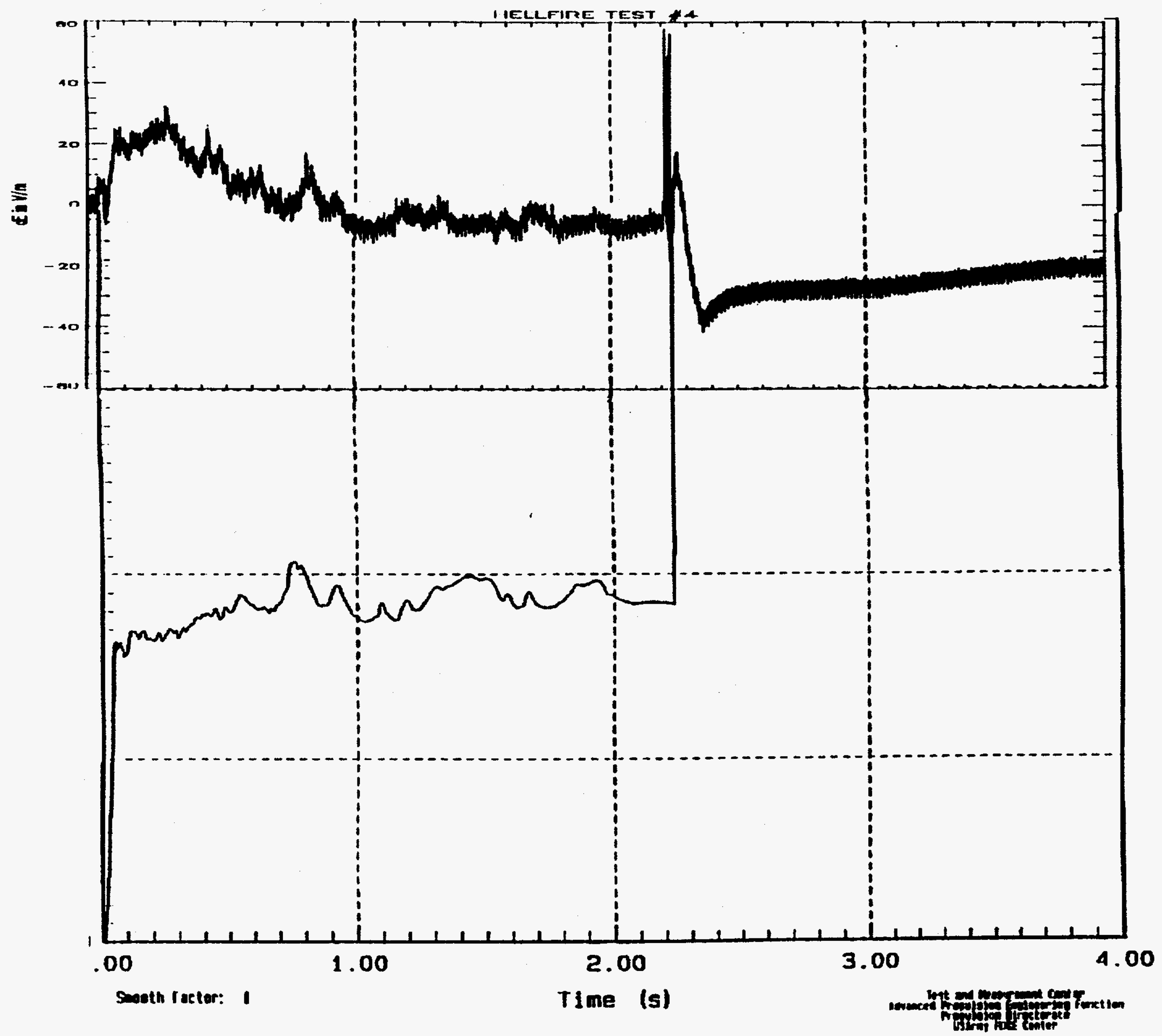

Figure 3. Data from anti-tank rocket motor. Top trace is the electric field and the bottom trace is the thrust. Rocket exploded at 2.2 seconds.