DISCRIMINATION OF CHEMICAL/BIOLOGICAL VS HIGH EXPLOSIVE ARTILLERY ROUNDS USING ACOUSTIC AND SEISMIC DATA FUSION

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ABSTRACT

The threat of chemical and biological weapons is a serious problem today and this threat is likely to continue in the future. The ability to determine if an incoming artillery round contains high explosives or a chemical/biological agent is valuable information to anyone on the battlefield. Early detection of a chemical or biological agent provides the soldier with more time to respond to the threat. By using acoustic and seismic sensors, the round type can be identified quickly after detonation and the threatened soldier alerted. This paper will describe the Army Research Laboratory's work with ground based acoustic and seismic sensors to discriminate between round types.

1. INTRODUCTION

The Soldier Biological and Chemical Command sponsored two field experiments to determine if chemical/biological rounds could be discriminated from high explosive rounds using various sensor technologies. The experiments included seismic and acoustic ground sensors, radars, infrared and video cameras, and meteorological sensors. Participants included groups from government, industry, and academia. The second experiment was performed in Dugway, Utah with artillery fire and detonation of HE and CB 155 mm rounds. The data presented in this paper are the acoustic and seismic measurements made during this experiment.

2. TEST DESCRIPTION

The sensors were located in three sites arranged in a triangle numbered in sequence of the sound incidence. Site 0 was at 540m from the expected detonation area and site 2 was on the same radial line at 1665m. Site 1 was 1026m radially out and 514m to the left from ground zero. The ground was relatively flat and brush covered in patches. The incoming artillery rounds were ground or air detonated at a height of around 100m. The High Explosive (HE) round has a larger amount of explosive (15 lb) compared to the Chemical Biological (CB) round (2 lb).

Each site had two high quality microphones with differing sensitivities to cover the wide dynamic range of the acoustic signal. The two microphones at each site were placed at 18in height and 8ft separation perpendicular to and bisected by the radian line from the source. Each site had a vertical and a tri-axial seismic measurement with locations two feet inside the microphone positions. The site positions were determined using GPS pluggers that also kept the computers in time synch. The data acquisition system at each site was triggered by a radio signal with only a few milliseconds jitter when the explosion was visually detected. The data was time synched again using the trigger pulse data from the radio trigger, calibrated, and stored in Matlab files named for each shot number and sensor.

3. Analysis

A digital high pass filter with a cutoff frequency of 15 Hz was used to remove wind noise problems that occurred on the most sensitive settings. A digital low pass filter with a cutoff frequency of 500 Hz removed the system noise and any interfering noise sources. The blast wave has a large distinctive low frequency content that is related to the explosive energy. This low frequency content is not attenuated as much over long distances as the high frequencies. Higher frequency blast wave parameters such as the rise time change rapidly near the blast due to atmospheric attenuation of the higher frequencies.

The arrival time and cumulative integral of the positive portion of the blast wave were calculated and entered into a table. The data in the table was used to display the trends in the values for each type of detonation. There was a small overlap in the positive cumulative integral values for close range CB air detonations and longest range HE ground detonations. The other parameter values that were calculated were less consistent in tracking the same trends. If the range to detonation information could be determined, the overlapping values could be eliminated.

The approximate range can be calculated from the detonation shock wave arrival times at three sites with known positions with the assumption that the source and sensors are in the same plane (e.g. Hercz, 1987). The more complicated solution is for the case where the sensors are separated by distances on par with the source range. The acoustic wave front in this case would be an arc across the sensor array. The blast wave arrival at the first sensor would set time zero for the array and subsequent arrival times at other array sensors would provide propagation distances for the blast wave arc between sensors.

A simpler case for direction finding would be if the sensor array dimensions were much smaller than the range to the source. This would allow the assumption that the wave front was a straight line, which simplifies the geometry to right triangles. A faster sampling rate is needed in this case to adequately determine the smaller difference separating arrival times at sensors across the array. A bearing would be calculated at each site and range would result from the intersection of site bearings from two sites.

The calculation of range from the acoustic waves being discriminated allows the ability to determine the approximate amplitude of the originating detonation by replacing the losses due to spherical spreading. This process would remove the uncertainty of a loud sound far away having similar energy content as a lower amplitude sound nearby. A prior knowledge of the energy content of chemical and conventional munitions and their acoustic blast wave parameters at a known distance would provide a template for comparison to acoustic measurements in the field with spherical spreading losses replaced. This comparison would result in the elimination of battlefield sounds that do not meet the energy content bounds for CB rounds from further examination.

A third way to determine range to the source at an individual site would be to calculate the time of arrival difference between the acoustic and faster seismic head wave. The head wave travels faster in the water table or rock layer. The difference in the arrival time of the surface and head wave allows an estimation of range. The head wave velocity in an area can be approximately calculated using the time difference between the two sites if the bearing to the source is known. The arrival of the seismic signals at different sites can be used as a large array in ranging similar to the acoustic method.

Other information about the source can be determined from the data. The seismic data amplitudes compared with the acoustic amplitudes can indicate whether the detonation was in the air or on the ground. The x-y portion of a tri-axial geophone data can give bearing information by comparison of relative amplitudes of each axis and the orientation of the sensor. Inside 1000 meters, the HE round data consistently contains a high frequency whine prior to the blast wave that is assumed to originate from the supersonic shrapnel. This phenomenon is not present in the CB round data.

Meteorological information for the area is included in the table to allow sound speed corrections and frequency loss predictions over distance. The meteorological data needed is the temperature, relative humidity, wind speed and direction, and barometric pressure. The temperature and wind are the major factors affecting the speed of sound. Corrected sound speed will improve the accuracy of the parameter calculations for the table.

3. CONCLUSIONS

The limits of the characteristics that define a CB round can be determined for the blast wave parameters given the source type and range. The limits can be determined by measurement or by predicting the acoustic signature from the weight and type of explosive. Information determined from the data such as detonation range and bearing and air or ground detonation allow the limits to be more accurately applied. Detonation signature identifiers such as the shrapnel whine associated with HE rounds can provide additional confidence in discrimination. Future work in this area will determine the effective range of discrimination for a given sensor sensitivity and meteorological conditions. A reasonable sensor configuration for this application can be determined from sensor cost, power consumption, size, sample rate, etc. for future applications.

As a part of the Objective Force Warrior concept, this sensor could be integrated into a soldier’s helmet, a vehicle or shelter, or distributed as stand-alone sensors. Each soldier would then be an information node that would relay small packets of information such as soldier location (GPS), event characteristics, and event time. The signal processor in the sensor performs all the local calculations on the data stream and relays only a small data packet back to the central processor. A central processor would then work on the big picture, using packets to calculate range and bearing information. The omni-directional acoustic/seismic methods of locating events of interest could then be used to direct focused assets like radar or infrared detectors. The fusion of these methods of detection would combine the strengths of each providing a higher confidence in the result.

REFERENCES

Col. (Ret) Arthur R. Hercz, “Fundamentals of Sound Ranging”, 1987, Dept of Math Sciences, West Point