Detection of Small Arms Fire.

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1. Introduction

Since April 1996 MacDonald Dettwiler (MDA) and the Defence Reseach Establishment ValCartier (DREV) have conducted research into the detection, localization, and classification of small arms fire. The result of this research and development is a commercial product, Guardian, that detects, localizes, and classifies small arms fire. The motivation for this development effort was to protect Canadian peacekeepers in locations such as Bosnia. This paper describes small arms fire events, and how the atmosphere affects those events. The detection techniques we investigated are described, along with our conclusions on the most effective detection technique.

2. Small Arms Events

When a small caliber weapon is fired, there are two events that occur. First, the explosion of the gun powder creates a muzzle blast. The intensity is generally strongest in the direction of fire and weakest behind the weapon. The duration of the muzzle blast approximately 2 ms, and has a peak intensity in excess of 155 dB. A typical acoustic event is shown in Figure 1.

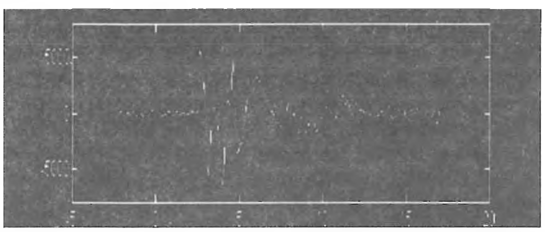

Figure 1. Acoustic Wave from a 7.62 mm rifle fired 200 from the sensor, towards the sensor. (25 ms of data)

The other event that occurs is a shock wave due to the supersonic bullet. The duration of the shock wave is approx 0.5 ms, and it also has a peak intensity in excess of 155 dB. The shock wave travels conically outwards from the line of fire of the bullet, at an angle given by, q = asin (1/M) where M is the bullet Mach number. Typically the initial velocity of the bullet is between Mach 2.5 – 3.0. The shock wave is only detectable in the forward arc of the weapon. Figure 2 shows the shock wave that occurred before the event in figure 1.

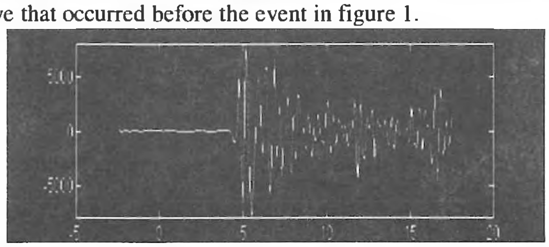

Figure 2.: Shock Wave, 7.62 mm rifle fired 200 meters from the sensor. (25 ms of data)

Because the bullet travels supersonically, the shock wave always arrives at a receiver before the acoustic wave. It also arrives from a different direction. These two properties affect small arms event detection and localization since the acoustic wave can be masked by the shock wave, and because the shock wave does not provide localization information for the source of fire. Therefore, a system like Guardian must be able to detect the weak acoustic events that occur after much stronger shock events in order to localize the source of fire. As the time of arrival difference approaches zero the shock and acoustic waves become mixed. This can cause a system to localize on the shock wave and produce errors that are slightly biased by the shock wave direction. Figure 3 shows the time difference of arrival of shock and acoustic waves as a function of receiver location relative to the shooter at the origin. The direction of fire is along the x-axis (into the page). The red section on the top right indicates that the shock wave does not reach those positions. Figure 4 shows the angular difference of arrival of the events. A system would only have difficulty distinguishing the two events when the time difference is less than 0.05 seconds.

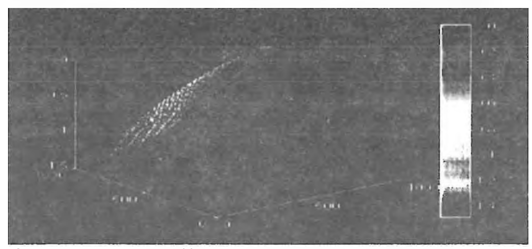

Figure 3.: Time difference of arrival of shock wave before acoustic. X and Y axes units are meters, Z axis is in seconds.

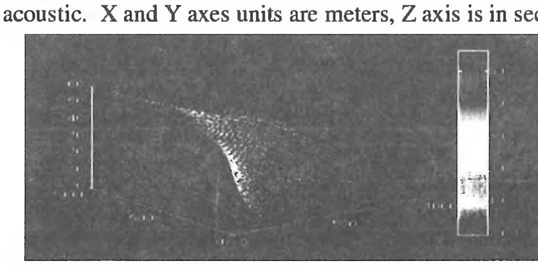

Figure 4: Angular difference of arrival of shock and acoustic waves. X and Y axes units are meters, Z axis is in degrees.

3. Atmospheric Propagation

The atmosphere affects the propagation of the small arms fire events through three primary mechanisms: absorption, refraction, and the geometry of the event. Absorption limits the distance that a high frequency sound can travel, so that frequencies higher than 2 kHz are effectively attenuated after 200 meters[1]. In our application, the atmospheric filter tends to remove some of the frequencies that help distinguish shock waves from acoustic waves.