



Electro-optical passive sniper detection — conception and system overview

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Abstract. The paper presents modern sensor systems for sniper detection. Among such systems there are active and passive optoelectronic devices. Its primary advantage is the possibility of early recognition of the threat, before the sniper is able to take the shot. Presented passive systems employ thermal cameras and advanced image processing algorithms to distinguish the sniper and muzzle blast signatures. Active systems, in turn, rely on the detection of laser radiation, retro reflected from pointed optics (optical sights and observation scopes). The paper presents basic technical and tactical characteristics of sniper detection devices, both standalone and included in multi-sensor detection systems.

Keywords: sniper detection, muzzle flash detection, infrared detection

Universal Decimal Classification: 621.38:537.533

1. Introduction

Sniper detectors are still a work in progress. The acoustic detectors have had the most success, and over 500 of them have been shipped to Iraq and Afghanistan. Sniper detection systems provide directional information about where the snipers are. Several generations of these systems have showed up over the last three years. The usefulness of these anti-sniper systems has increased as the manufacturers have decreased the number of false alarms and improved the user interface. There are other reasons for all this progress, including major advances in computing power, sensor quality and software development. The modern, improved systems provide nearly instant and easy to comprehend info on the sniper location.

The primary phenomena used in sniper detection are: acoustic signal from the shockwave generated by a supersonic bullet and the muzzle blast, optical signal from the muzzle flash, and retro-reflection from the optical sight. The bullet can also be detected optically in flight. Here, the muzzle flash will be discussed. This type of sensor can also provide both cueing of other sensors and substantially reducing the false alarm rate. The flash image can also be shown to an operator for inspection.

The most important aspect of counter-sniper actions is the ability to detect the sniper before he could take a shot. Such task can be accomplished by passive and active optoelectronic sensors. The former are usually thermal systems with search and track capabilities, whereas the latter are laser systems which detect reflections from optical sights. The advanced methods of analysis of reflected laser radiation can distinguish objects of interest from the reflecting elements of scenery, like windows and car headlamps.

2. Shot phenomena

The phenomena detected in IR spectra are muzzle flash and thermal signature of the bullet in flight. Muzzle flash is an IR signature associated with the ejection of the bullet from the sniper's rifle. The muzzle flash can be detected with IR sensors out to a kilometre or more, but the sensors must have line of sight to the weapon, and the flash can be suppressed. The thermal signature of the bullet in flight can be detected with IR sensors out to several kilometres in range. Since the bullet is much hotter than "room temperature", it is detected most effectively in the medium-wave infrared (MWIR) band, with wavelength between 3 and 5 μm . However, long-wave infrared (LWIR)-based systems operating in the wavelength band between 8 and 10 μm can also detect such signatures. The object of detecting signatures of the bullet in flight is to estimate the bullet's trajectory and backtrack it to find the location of the sniper [1, 2].

The flash spectrum varies with the chemical reactions but consists generally of a continuum and various line and band spectra. Line spectra in the visible and near infrared are often caused by sodium and potassium, parts of the flash suppressants. Band spectra are observed in the short and mid wave infrared spectral region due to hot water vapour and heated carbon dioxide. The gas leaving the combustion area is still hot and stays for a time much longer than the flash duration. This radiation can be detected in the thermal spectral region and does not require the same temporal resolution.

Visual image intensifiers and vision sensors are dependent on ambient illumination for signature generation. They depend both on a reflectance difference between the target and the background to create contrast and on the availability of sufficient reflected ambient illumination to create an adequate signal level. Given

adequate illumination, visible and near-infrared signatures ultimately depend on the spectral reflectivity differences between the target and the background in the sensor response band. Visual sensor can use photopic colour differences as a discriminant. Image intensifiers extend the visual spectrum out to approximately $0.9 \mu\text{m}$ or into the near infrared. Using silicon detectors the sensitivity can be extended out to approximately $1.1 \mu\text{m}$. These near IR sensors can exploit the high reflectivity of live foliage and the low reflectivity of conventional paints to see a large negative contrast difference between the target and its background. Figures 1 and 2 present sample sniper pictures registered in visible and IR spectra during field tests at the Military University of Technology.



Fig. 1. Sniper images registered by a visible camera



Fig. 2. Thermal sniper signatures recorded before and during shooting

The development of optical system designed for sniper detection concentrates on several aspects. They are: design of optics, new types of sensors, and signal processing methods. As far as infrared detection of explosive event (i.e. muzzle flash) is concerned, the optimal wavelength range, covering sniper fire, mortar fire and rocket propelled grenades (RPGs) lies between two spectral bands, one centred at $2.8 \mu\text{m}$ and one at $4.5 \mu\text{m}$. Therefore, the mid-IR range (MWIR) is commonly chosen, which means that a sniper detection system operating in the 3 to $5 \mu\text{m}$ wavelength range must deal with the potential problem of false alarms from solar clutter. The detection of muzzle flash requires fast reaction times and scanning rate.

After taking position, the sniper usually fires one shot at selected target. The shot generates muzzle flash and shock wave (muzzle blast). First phenomenon can be detected in various spectral ranges: UV, visual, and IR. The muzzle flash is a result from a sequence of events in which overexpansion of muzzle gases causes the formation of a normal shock wave. Studying muzzle events associated with formation of weapon flash, phases of flash can be determined: primary flash, pre-flash, intermediate flash, muzzle glow and secondary flash (Fig. 3) [3, 4, 5]. Primary flash it is a small zone immediately adjacent to muzzle of the gun being simply an extension of the flash inside the barrel. It may exist before or after projectile emergence or at both times depending upon whether an appreciable amount of leakage of the propellant gases around the projectile occurs. It may be a white flash indicating actual burning or it may be a reddish glow due to incandescent solids being present in a hot compressed volume of gas. A low-pressure burning of gases which have leaked around the projectile before its emergence from the barrel — it is starting pre-flash. The combustion is supported by oxygen within the barrel before a round is fired. While pre-flash is initiated before projectile emergence, its duration may vary considerably — depending upon the amount of gas leakage and the resulting temperature and pressure of the gases responsible for pre-flash. When started intermediate flash, usually triangular-shaped incandescent zone can be seen that appears approximately 20 calibres ahead of a muzzle. The base of the triangular zone coincides with the strong shock front forming nearly the flat

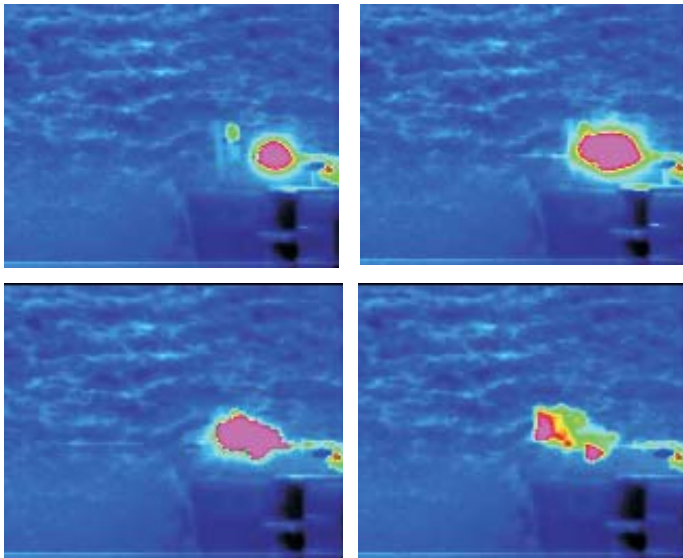


Fig. 3. The phases of muzzle flash (AK47, cal. 7.62 mm — the measurements registered during field tests at the Military University of Technology)

forward boundary of the shock bottle, the apex of the triangle points away from gun. The colour of this flash is usually red or reddish-orange and the temperature is roughly 1200 K to 1500 K. This is to be contrasted with secondary flash which appears as a bright-yellow flash with a temperature of approximately 2200 K.

An illumination of the zone enclosed by the shock bottle is a muzzle glow phase. This zone extends from the muzzle to the shock front responsible for intermediate flash and has lateral boundaries coincident with the shock bottle. This is a very weak, rarely observed flash. A large voluminous flash which is initiated in or near the intermediate flash region and spreads in all directions is the secondary flash. This flash is a low-pressure burning of combustible gases which have issued from the muzzle of the gun and mixed with atmospheric air [4].

The phases of a shot event with corresponding temperature changes have been shown above in Fig. 4. The analysis of the shot detection in different spectral bands revealed, that very little information is available on the ultraviolet radiation of gun flash. It was found that possibly only in 404.4-404.7 nm range, the strong line of atomic potassium can be detected by UV sensor. However, during both computer simulations and real measurements no UV radiation was detected during shot recordings from various types of weapons (the experiment details are presented below). The spectral shot characteristics presented in Fig. 4 clearly indicate that most of the muzzle flash energy falls into near infrared range, which is decisive for shot detection. Muzzle flashes generally peak in the 2.5-3.5 μm region (H_2O) following 800-1400 K blackbody curves corresponding to water vapour lines and have other peaks at 2 microns and 4.7 microns. As the target range increases, the radiances in the 1.7-2 μm , the 2.4-3.4 μm , and 4.0-4.5 μm range decrease rapidly [4, 5, 6].

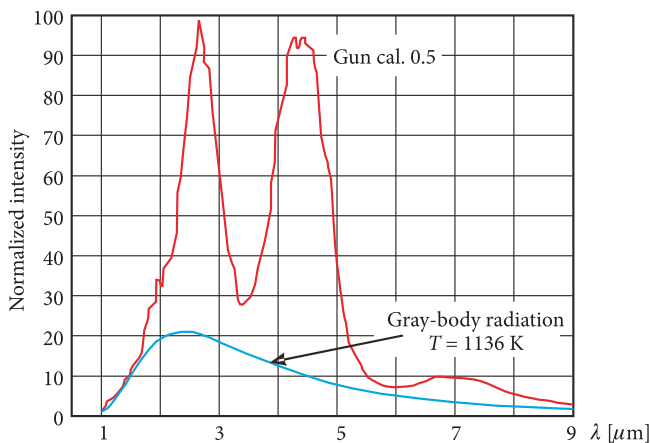


Fig. 4. The spectral distribution of infrared radiation from secondary flash (caliber 0.50, gun barrel length 36 inches) [4]

3. Laboratory measurements of shot signatures

Laboratory test measurements were carried out in order to determine reference temperature distribution associated with the shot event. MUT has specialized laboratory facility (Fig. 5) for the recording of rapid processes accompanying the shot from weapons up to 0.50-calibre. The recordings in wide spectral area can be performed as well as the measurement of other parameters, projectile velocity included. The measurements and recordings were carried out in visual, MWIR, and LWIR ranges. The main objective of the laboratory tests was to gather data for the determination of the discriminative features of thermal signatures of the shot without the disturbing effects of atmospheric influence. The objective of the field tests was the same as at laboratory tests but in the real environment.

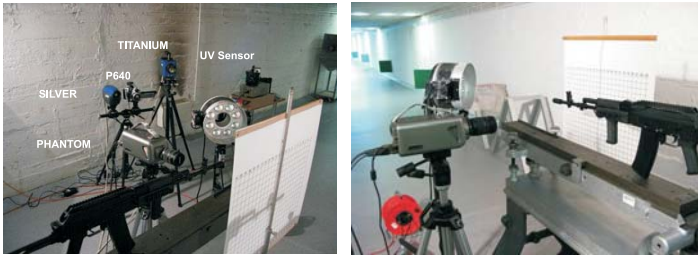


Fig. 5. The laboratory stands for the measurement of the shot signatures

The recordings of sample thermal images were performed in the MWIR and LWIR ranges at a laboratory test stand. The thermal cameras operating in ranges 3.7-4.8 μm and 7.5-13 μm and a super-fast visible camera were used for the recording of shot images, which made it possible to observe wavelength-dependent differences.

Four measurement devices were used:

- IR camera SILVER (Flir Systems — Cedip) 3.7-4.8 μm ;
- IR camera TITANIUM (Flir Systems — Cedip) 7.5-11.5 μm ;
- IR camera P640 (Flir Systems) 7.5-13 μm ;
- VIS camera Phantom 0.8-0.9 μm .

Two different weapon calibres were tested:

- cal. 5.56 mm — Beryl assault rifle;
- cal. 7.62 mm — AK 47, SVD.

The laboratory measurements were performed in two stages. During the first stage, the shots were registered from 1 meter distance at an angle of 90 degrees, with frame rates up to 870 Hz. Shots were repeated in 3-minute intervals. The shooting were registered by all infrared cameras, positioned accordingly to view approximately the same measurement area. In the second stage, the measurement distance was 10 meters and an angle between cameras and gun barrel was 25 degrees. Again,

the shots were repeated in 3-minute intervals and the shooting were registered by all infrared cameras. The frame rates were up to 700 Hz.

4. Field measurements of sniper and shot signatures

The field tests were performed in order to determine the temperature distributions before, during, and after the shot. The test location on the MUT shooting range made it possible to perform the measurements in the “real” environment, under different weather conditions (Fig. 6). Weapons up to 7.62 mm calibre were tested on the range and various types of recording devices were used, like MWIR and LWIR cameras and fast visual cameras. The measurement methods used during the recordings and sample results are presented. The main objective of the field tests was to gather data for the determination of the discriminative features of thermal signatures (Fig. 7). The recordings of sample thermal images were performed in the short and long wave range of infrared spectrum for different weather conditions. The devices used for the recording of thermal images were operating in ranges 3.7-4.8 μm and 7.5-13 μm . During the measurements, the sniper fired single shots in 1-minute interval. The frame rates were changed from 100 Hz up to 870 Hz.



Fig. 6. The infrared cameras during the measurement at ground test field (a); sniper prepared to shoot (b); ALTAIR software for the analysis of IR images (c)



Fig. 7. The sniper shot at ground test field (a); sniper at terrace of a building (b); rifle shot SVD cal. 7.62 mm (c)

The distance between an object and the measuring devices was 30 meters and the recordings were taken at an angle of approximately 45 degrees.

During the field tests, there were also measurement performed, in which the angle between gun barrel and camera line-of-sight was only 10°. As a result, the recordings show the shot aimed nearly at the measurement cameras and thorough analysis is possible of the temperature changes during all stages of sniper activity: before, during, and after the shot.

During measurement sessions at MUT shooting range, the shot signatures were recorded to extract characteristic features suitable for sniper detection. Several continuous recordings were performed at different frame rates (from 100 to 630 fps) and different integration times of camera detectors. Such wide variety of recording parameters will allow further analysis and optimal choice of device parameters for successful sniper shot detection. Recorded shot sequences were compared during subsequent analysis and further optimization of parameters was possible. Finally, recorded data were catalogued, included in the database and the appropriate documentation was worked out. The temperature histograms for the selected areas were calculated for the quantitative analysis of infrared emission. The sizes of the areas of uniform temperature were calculated by counting the corresponding number of pixels and using the geometric relations between the angular dimension of a single pixel and the distance to object [7, 8]. The histograms were calculated on the basis of the whole target area and representative part of surrounding background. The thermal images were converted, for the need of numerical calculations, into matrixes of irradiance at the detector plane. As a result, object thermal signatures were obtained. The temperature changes versus time were also calculated, which gives additional information about sniper signature before, during, and after shooting. The gathered data will be utilized during the design of multispectral sniper detection system [9].

Apart from shot recordings, the thermal signatures of the sniper and background before the shot were also registered. It was intended to obtain specific sniper body signatures and to determine the parameters suitable as criteria for sniper detection before the shot by IR devices. The sniper detection before the shot is most important in counter-sniper actions regardless of detection devices used. The recordings were performed in forested area, open terrain and urban area, with sniper hidden inside a building.

5. Analysis of the measurement data

Laboratory measurements were aimed at recording the signatures of particular phases of a shot in a controlled environment (Fig. 8). Analyses of those signatures make it possible to determine temperature changes during the whole muzzle flash

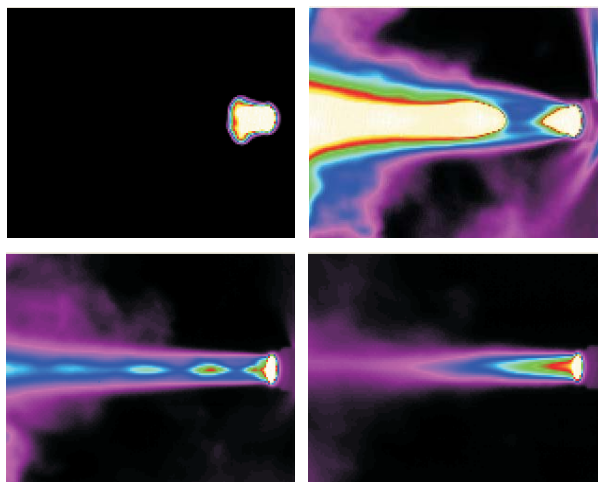


Fig. 8. The phases of muzzle flash registered during laboratory test (Beryl assault rifle, cal. 5.56 mm)

event. Additional recordings were also made using ultra-fast Phantom camera and UV sensor, to investigate the possibility of shot detection in visual and UV spectral bands and to analyze chemical composition of a gas cloud [10].

All field tests were performed in winter season and such parameters as distance, ambient temperature, wind speed, atmospheric pressure, and humidity were monitored. The recordings for different weapons were made at the same time to obtain comparable results in similar weather conditions. The results of registrations were evaluated using the ALTAIR and ThermoCAM RESEARCHER Pro software.

The first stage of measurement data analysis concerned the signatures recorded during laboratory tests. During the recording session, several shot signatures were registered to obtain broad range of measurement data. Analysis was mainly focused on temperature changes throughout the muzzle flash. An example is shown in Fig. 9, where the thermal image is presented and corresponding temperature values at the selected point are shown in the consecutive frames recorded during the shot.

Both thermal cameras (Silver and Titanium) were set at maximum frame rate of 630 Hz. In this case, several frames could be recorded during muzzle flash duration and sufficient amount of data was obtained for further analysis of temperature changes during shot.

In the next phase of data analysis, the temperature parameters were to be determined, characteristic for different stages of sniper activity. Figure 10 shows sample signatures before, during, and after the shot with distinguished areas (1— sniper body and weapon, 2 — close neighbourhood), for which temperature analysis was performed. The corresponding results, summarized in Table 1 show temperature values and statistical parameters obtained for all defined stages of sniper activity.

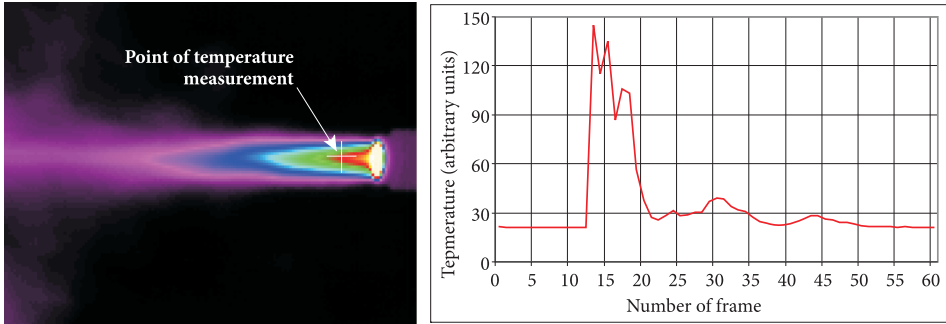


Fig. 9. The analysis of temperature changes during the shot (Beryl assault rifle, cal. 5.56 mm)

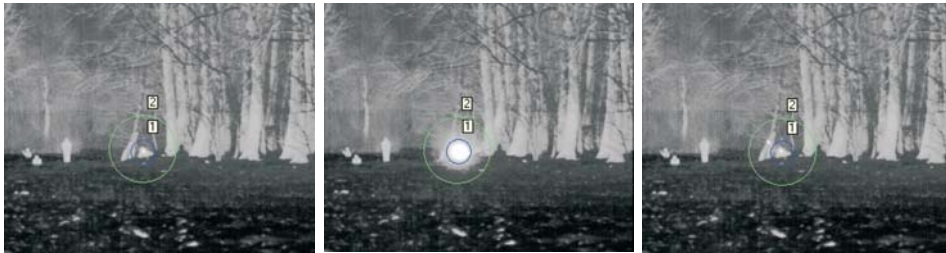


Fig. 10. The sniper signatures registered during field tests

TABLE 1

The results of temperature analysis during phase of sniper activities

Activities of sniper	Before shot		During shot		After shot	
	1	2	1	2	1	2
Area label	1	2	1	2	1	2
Min (°C)	-1.52	-1.88	2.69	-1.52	-1.54	-1.93
Max (°C)	12.93	12.93	58.12	58.12	12.58	16.43
Mean (°C)	0.42	-0.35	20.00	3.04	0.35	-0.36
Std-Dev (°C)	2.16	1.29	18.06	9.49	2.16	1.45

Figure 11 shows temperature change recorded during shot in both analyzed areas. The shot was recorded using Silver thermal camera with frame rate set at 383 fps. The recorded shot lasted 8 consecutive frames and temperature changes can be easily observed, including the effect of hot cartridge case ejected from the weapon. This example shows that shot detection capabilities of a thermal camera and the real SNR ratio is high enough to assure sniper detection.

In the last part of data analysis, the thermal shot signatures recorded for different weapons were compared. It was an attempt to classify the weapon type

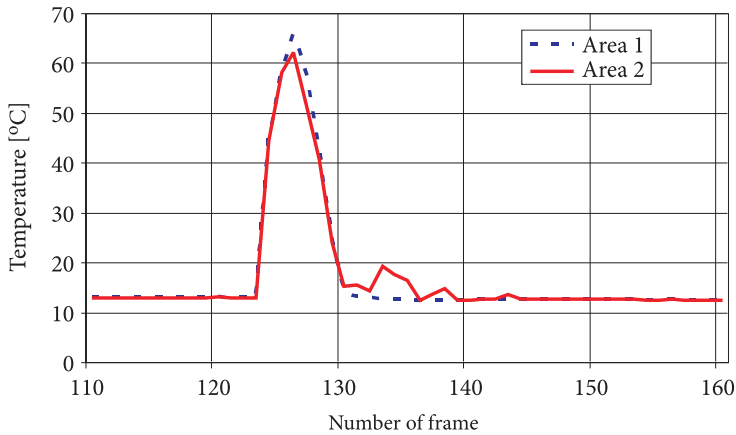


Fig. 11. The comparison of temperature change in both analyzed areas

on the basis of thermal signature. Unfortunately, as the data presented in Fig. 12 indicate, the temperature differences are very small and classification on this basis alone would be difficult.

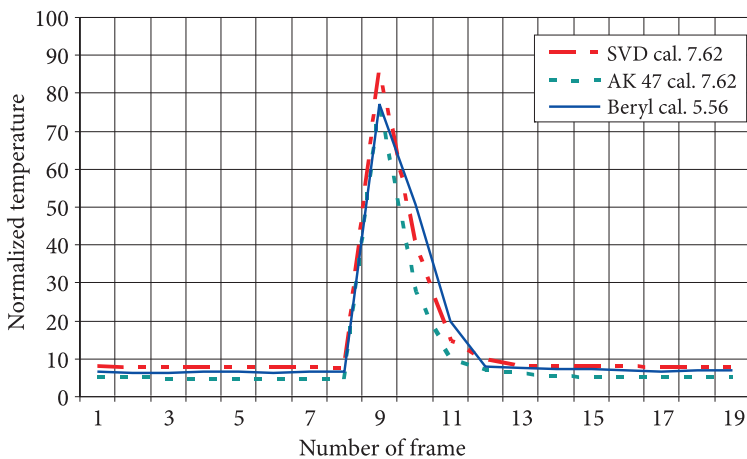


Fig. 12. The comparison of temperature changes during intermediate flash for different guns

During the tests no bullet signatures were recorded because of high velocity of a projectile and limitations introduced by frame rates of available thermal cameras. An ultra-fast thermal camera is required for such recordings and the acquired signature is of limited usability, as the application of such camera in the sniper detection system would raise the overall costs several times. There are other sensors much better suited for bullet detections than IR camera-based solutions (e.g. radar systems).

Bullet signatures were recorded during laboratory measurements using an ultra-fast Phantom visible camera. Sample image is presented in Fig. 13.

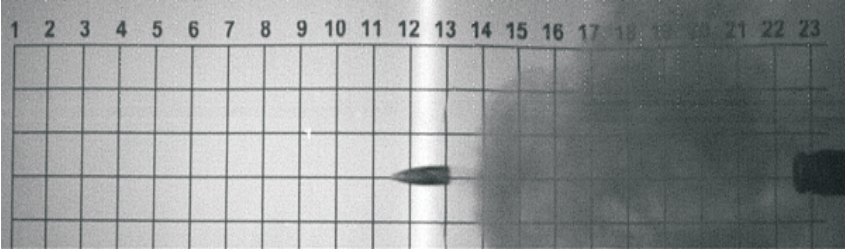


Fig. 13. The bullet fired from SVD sniper rifle

However, as the visible image relies on the ambient scene illumination, it is virtually impossible to record fast-moving object (which implies very short shutter speeds) in a wide FOV in a real sniper detection system. Cost-wise is the same situation as in case of thermal camera. As a result, projectile signatures in the visible spectral range were not considered.

6. The passive systems for sniper detection

Most commonly used acoustic sensors can measure angles to the acoustic source, but not the range. To establish a track of the bullet, it is required that an array of acoustic sensors is deployed. One alternative approach is to obtain an approximate direction to the sniper from the acoustic information, then to cue an IR sensor to backtrack the bullet more precisely. A second alternative is to detect the muzzle flash with a wide-field-of-view IR sensor, which then initiates an IR track of the bullet, resulting in a backtrack to the sniper.

The backtracking process in the city is complicated by buildings, which may obstruct the view of the sniper's location. If much of the bullet track is visible, it is feasible to use the computer simulation to complete the backtrack in the virtual world of the computer. This procedure could provide GPS coordinates for a weapon delivered from a UAV.

The table below presents the summary of sniper detection systems used by armed forces of the world, showing the physical phenomena those systems use for sniper detection. The data presented in this table were gathered from all commonly available sources of information.

TABLE 2

The systems for sniper detection

Name	Manufacturer	Muzzle Blast	Bullet Shock Wave	Muzzle Flash	Bullet in Flight (IR)	Optics Laser Reflection
Prototype	Sanders	X	X			
Bullet Detection Indicator	G D Associates		X			
Bullet Ears	BBN	X	X			
PD Cue	AAI Corporation		X			
VIPER	Maryland Advanced Development Lab			X		
Prototype	Hughes Aircraft	X			X	
Integrated Sniper Location System	Sanders, LMIIS, and Sentech	X	X		X	
SECURES	Alliant Techsystems	X				
Fast IR Sniper Tracker	Thermo Trex			X		

The development of optical system designed for sniper detection concentrates on several aspects. They are: design of optics, new types of sensors and signal processing methods. As far as infrared detection of explosive event (i.e. muzzle flash) is concerned, the optimal wavelength range, covering sniper fire, mortar fire and rocket propelled grenades (RPGs) lies between two spectral bands, one centred at 2.8 μm and one at 4.5 μm . Therefore, the mid-IR range is commonly chosen, which means that a sniper detection system operating in the 3 to 5 μm region must deal with the potential problem of false alarms from solar clutter. The detection of muzzle flash requires fast reaction times and scanning rates, significantly exceeding typical values of 30 or 60 Hz of standard cameras. It is not fast enough for detection of signals such as sniper fire, which is believed to have duration of about 2 milliseconds. Additionally, the wide field of view is necessary to scan the surrounding area yet retaining the possibility of pinpointing the location of the muzzle flash event (sniper location). Some examples of real IR systems for sniper detection are described below.

WeaponWatch, developed by Radiance Technologies, provides very capable, reliable and flexible weapon detection and response system. It provides a complete solution that detects, locates, classifies and responds to fired weapons from fixed and rotary wing aircraft, UAVs, ground vehicles, towers and tripods.

Employing a powerful infrared camera and high-speed 5th generation data processing technology, WeaponWatch recognizes and analyzes in real time the heat signatures of fired weapons. WeaponWatch's speed and accuracy make it possible to

detect and respond to enemy weapon fire-by alerting soldiers, by communicating the type and location of the weapon, even by returning fire-before the sound of the enemy weapon reaches the sensor.

WeaponWatch detects weapon fire in real-time day or night across a wide 120° field of view. Sensors may be stationary or “on the move.” WeaponWatch can identify individual weapons fired during simultaneous fire from dozens of weapons. It locates fired weapons by translating azimuth, elevation and range to actionable geocoordinates. WeaponWatch is integrated with the platform's guidance system to adjust for velocity and to classify detected weapons using a vast database of weapon fire signatures for small arms, sniper rifles, machine guns, RPGs, MANPADs, tanks, mortars, artillery, and others. WeaponWatch can detect fire from each of these weapons from beyond its effective range. System responds instantaneously with the detected weapon's type and geolocation, cuing integrated sensors, weapons and other systems while transmitting detection and response event data to command and control systems. WeaponWatch's user interface delivers detailed visual information with man-in-the-loop engagement control.

Detecting and responding to enemy weapon fire, WeaponWatch combines infrared sensor fidelity and super high-speed data analysis to enable warfighters to instantaneously detect, locate, and classify firings of a broad range of weapons. The basic elements of this system are shown in Fig. 14. Warfighters and security personnel are under increasing risk from sniper fire and drive-by shootings. These terrorist acts succeed largely because of the difficulty in detecting and locating the enemy fire. Forces engaged with Operation Iraqi Freedom (OIF) are employing this system today to provide exacting targeting information in both urban and open terrain.

WeaponWatch picks up on the infrared signature of every weapon the moment it is fired, instantly identifying it from a database of thousands of weapons muzzle flashes and relaying its position on screen. It has already proven itself in combat. The older, fragile, 400 pound version of this system was tested in Iraq, on top of a building where there was a high concentration of insurgent gunfire. Within a few days, it turned out that American troops were able to use WeaponWatch to return fire more rapidly, resulting in a noticeable drop in enemy attacks [11].

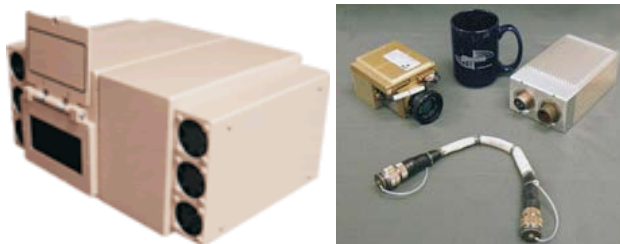


Fig. 14. Elements of WeaponWatch system

No anti-sniper system is perfect, of course, and any system can be fooled or exploited once enemies get a good enough sense of what it can and cannot do. The potential of combination of acoustic Boomerang and infrared WeaponWatch sensors, however, may give American forces the multi-modal capability they need.

The REDOWL system, presented in Fig. 15, is another, mobile sniper detection system. It features an Acoustic Direction Finding (ADF) system developed by BioMimetic Systems. The ADF is based on advanced “neural circuits” emulating human hearing and provides accurate detection and bearing information in high background noise environments. System uses laser pointer and illuminator, acoustic localizer and classifier, thermal imager, GPS positioning, an infrared and daylight camera, and two wide-angle cameras. In addition to providing its PackBot robot platform, iRobot developed the software and behaviours for the robot. Insight Technology, a manufacturer of high-performance visible and infrared laser and illuminator systems, is heading up the development of REDOWL’s optic systems. BioMimetic Systems, a Photonics Center portfolio company, is responsible for REDOWL’s acoustic detection and location systems. The Army Research Laboratory is the primary source of funding for this project.

REDOWL is a remote, deployable sensor suite designed to provide early warning information, gunshot detection, intelligence, surveillance and targeting capabilities to military forces and government agencies. The REDOWL equipped PackBot has been field-tested for the Army’s Rapid Equipping Force at a rifle and trapshooting range. Of the more than 150 rounds fired from 9-mm pistols, M-16 and AK-47 rifles from over 100 meters, the REDOWL system located the source of the gunfire successfully 94 percent of the time.

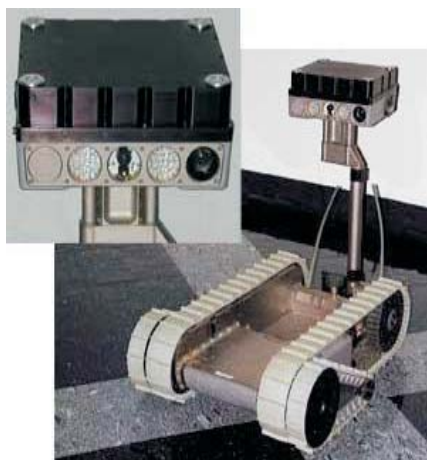


Fig. 15. REDOWL system mounted on PackBot tactical mobile robot

The iRobot PackBot is a Tactical Mobile Robot that can be hand-carried and deployed by a single soldier. Proven in Afghanistan and Iraq, PackBot searches dangerous or inaccessible areas, providing soldiers with a safe first look so they know what to expect and how to respond.

REDOWL features an array of optics and acoustic detection systems including a laser pointer and illuminator, acoustic localizer and classifier, thermal imager, GPS positioning, an infrared and daylight camera, and two wide-angle cameras. When integrated with the PackBot, these systems enable the robot to accurately detect, locate, and identify the origination point of hostile gunfire. These systems also make REDOWL ideal for day and night urban surveillance, reconnaissance, hostage/barricade situations, forward observation outposts and perimeter protection missions.

7. Conclusions

The analysis of data recorded during the experimental measurements shows, that the detection of a gunshot in visible and infrared spectral band is not a very complicated task. The effective usage of both spectral bands for the shooter detection require, however, considerable amount of experimental data for full description of the real shot parameters. Such data, called signatures, are the basis for the development of efficient algorithms for shot detecting devices.

Passive and active optoelectronic systems are effective weapon in anti-sniper operations. Its primary advantage is the capability of early detection of a potential threat. Such systems are versatile ones and they can operate as standalone devices or as a part of multi-sensor systems. The integration of different sensors into one detection system increases the probability of detection and reduces the false alarm rate. With the range matching the striking distance of sniper attacks, optoelectronic systems are very effective in modern battlefield conditions. Positive results of operational use of such systems prove that they provide a higher level of troops protection, especially in recent asymmetric conflicts.

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Pasywne wykrywanie strzelca wyborowego — koncepcja i optoelektroniczne systemy wykrywania

Streszczenie. W artykule przedstawiono współczesne systemy detekcyjne przeznaczone do wykrywania snajpera. Wśród systemów tego typu, wprowadzanych na uzbrojenie wielu armii istotną rolę pełnią pasywne i aktywne systemy optoelektroniczne. Ich zaletą jest możliwość wczesnej detekcji zagrożenia, zwłaszcza przed oddaniem strzału przez snajpera. Przedstawione systemy pasywne wykorzystują kamery termowizyjne i zaawansowane metody analizy obrazu w celu wykrycia sygnatur snajpera i strzału z broni palnej. Systemy aktywne wykorzystują z kolei promieniowanie laserowe w celu wykrycia optycznych przyrządów celowniczych i obserwacyjnych.

Słowa kluczowe: detekcja, termowizja, analiza obrazu, systemy optoelektroniczne

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