Study of electro-optic surveillance system to development of new obscuration smoke system for military vehicles

GHEORGHE BOGDAN PULPEA¹, DANIEL ANTONIE¹

Abstract: Camouflage action of military troops and objectives is considered as one of the main measures taken against enemy attacks since the First World War. As a response to this impediment, to surveillance and firing to the target in the battlefield, and reduce the advantages of night combats, were gradually developed high-performance optical devices in the visual (VIS) and infrared (IR) spectrum. So implement the camouflage measures is becoming increasingly difficult. This article represents a step in the way author to developing a new obscuration smoke system in VIS and IR, generating smoke screens, and it is part of a series of other papers outlining PhD thesis. Through this article aims knowledge of electro-optic system in VIS and IR, given the performance, organization and their functioning that lead to the formulation of performance that must be fulfilled by the smoke/obscuration protection systems.

Keywords: thermal system, optical sensor, infrared, electro-optic, night vision.

1. Introduction

Optoelectronics has today spectacular dynamics among technology areas are expected in the future due to advantages, its role will be increasingly important in society. It is a land border between optics, electronics, mechanics, cybernetics, informatics, automation, advanced technology, etc.

To adopt effective measure masking is necessary to know the level and direction of development of technology research in VIS and IR spectrum and electromagnetic guidance (fig.1). Electro-optic research aims discovery military

¹ Military Technical Academy, 39-49 George Coșbuc Ave., Sector 5, 050141, Bucharest, Romania, bogdy_203@yahoo.com
combat, weapons and enemy combat equipment that emit infrared radiation, determining coordinates land targets, air and marine, discovering assemblies and movements of troops and military equipment.

*Figure 1. Screen smoke in VIS and IR spectrum [3].*

In purpose of detecting targets, driving and firing at night, it was necessary to develop special optical devices – night vision devices (night vision pseudo/mono-goggles, binoculars, night vision monocular, rangefinder, night vision rifle scopes) (fig. 2).

*Figure 2. Different types of night vision devices [18].*

As you know, any object of heat generator is a source of infrared radiation (fig. 3), the most important being missiles, planes, tanks, armored personnel carries, vehicles, gun turret, especially during engine operation or firing, but also a few hours after cessation of these actions [1].

*Figure 3. Thermal images [19].*

In observing at night are discussed usually about three phases of observation: detection, recognition and identification [2]:

- Detection: it requires notification of the target, as something different to background and of interest;
- Recognition: it involves setting target shape, allowing its classification;
- Identification: as the final phase of observation, should allow individualization of the target.

2. General principles

Theoretically, the spectral emission is infinite: but practical, due to strong absorption phenomena of atmospheric environment, the useful is between 0,75 and 20 μm (micrometers) so divided: near infrared – NIR (0,7 - 1 μm); short-
wavelength infrared – SWIR (1 – 3 μm); mid-wavelength infrared – MWIR (3 – 5 μm) and long-wavelength infrared – LWIR (8–14 μm) [2].

In the development stages of observation systems in VIS and IR were outlined a number of general issues underlying the organization and determines their operating principles [2]:

- In NIR and SWIR regions, energy must be reflected from the target to produce quality images, which means that there must be external lighting (radiation from the sun, moon and stars) or an additional source of infrared radiation (Light Emitting Diodes – LED) (fig. 4);

![Figure 4. Image intensified night vision](image)

- One advantage of systems that work in NIR and SWIR regions (night vision systems), is the fact that the glass allows the passage of radiation with a wavelength of less than 3 μm (able to detect targets located after the window);

- For the optical system is sufficient use of glass, which is much cheaper than germanium or silicon necessary systems that work in MWIR and LWIR;

- Analog night vision devices should not be used in daytime, they can be damaged by exposure to bright light [18];

- MWIR and LWIR regions are often called thermal regions (fig.5);

![Figure 5. Thermal images (total darkness)](image)

- An equipment operating in thermal regions (thermal systems) can be completely passive and do not need artificial or natural light source, as it detects radiation emitted by objects and not one of them reflected (figure 6);

![Figure 6. Observing the target in total darkness (low light)](image)
by thermal infrared technology [15].

- In this case, the image quality formed by a thermal sensor is dependent on two factors: temperature and emissivity of the object observed;
- Glass is opaque to the passage of LWIR regions and blocks almost all the energy radiation in the MWIR region (fig.7);

![Figure 7. Thermal image through glass [20].](image1)

- Systems that work in MWIR and LWIR region cannot use cheap glass lens, requiring the use of other materials more expensive;
- Thermal systems are slightly more tolerant than night vision systems, as regards inside dark buildings, or in conditions like dust storms, smog, etc. (fig.8);

![Figure 8. Night vision and thermal image on smog [15].](image2)

- Thermal signatures by day and night is very different because solar charging during the day: for example, parts of the turret and the outer body can be very cold at night, making them hard to detect, while day, they become easily detectable due to solar heating.

By type of electronic components it uses and mode of operation of the device, optical devices are classified:
- Night vision devices active type;
- Night vision devices passive type: divide in image intensified night vision devices and thermo vision devices.

Active night vision devices are those systems that require operating an additional source of infrared radiation. The objects are illuminated with an infrared illuminator and reflected radiation is collected, processed and visualized. These systems have the disadvantage that the enemy, equipped with IR radiation-sensitive devices, can locate lighting reflector and can destroy it; also strong sources of infrared radiation affecting the functioning of these devices. These devices are part of the first generation of night vision which first used Image Intensifier Tube (IIT) called Generation 0 (Gen 0). Note that these
devices are no longer in military use only for civil systems use (building supervision, interiors) (fig. 9) [2].

**Figure 9. Night vision camera Gen 0 [21].**

Night vision technology uses image intensification such as monocular, binoculars to see details at night because it works by intensifying the existing light spectrum. Low levels of ambient light pass through a photocathode that converts the light photons to electrons, and then amplifies them. They then hit a phosphor screen where they are converted into visible light (fig.10). The phosphor screen is colored in green because the human eye can differentiate more shades of green than other phosphor colors [19].

These devices do not require auxiliary lighting, but using residual light coming from cosmic radiation sources and atmospheric.

**Figure 10. Operating diagram for passive night vision system, modified from [2].**

The passive night vision industry has evolved through four generations of development. It started with Generation I, which is an improvement on Generation 0 technology, around 60s, characterized by geometric distortion, short-lived, large size and poor performance, finishing with Generation III plus (sometimes called Generation IV), which brings further improvements in technology, which has a high resolution and can detect images at a level of less than 0, 00001 lx (multiply ambient light by as much as 50000 times).

Thermal systems are devices based on the thermal contrast that it presents the objects (targets) in relation to the environment in which is located, when they have a temperature that differs from that of the environment (fig.11).
People, military combat vehicles (their engines), aircraft have a very good heat signature in relation to the environment in which it is being easily detected by night vision using thermo vision principle (fig.12).

Thermal imaging cameras have the basic operating principle converting infrared radiation collected by the lens, in electrical signal, processed and posted on a display (fig.13).

In principle, a thermo vision devices is consists of:

- Object glass, that collects and focuses the infrared radiation on detector matrix,
- Detector matrix, which converts the thermal energy into an electrical signal;
- Electronics, which processes the electrical signal and displays the resulting image on a display.

The thermal imaging cameras have evolved through three generations of development, depending on the technology of thermal detectors. They also can be divided into two categories, such [2]:
• Thermal cameras with cooled detectors at a temperature of -200°C (InSb detector operating in spectral range of 3-5 μm);
• Thermal cameras with un-cooled detectors (operating in spectral range of 8-12 μm);

In addition to these systems to facilitate observation and the aiming of the target, over time appeared different types of optical systems that can determinate the distance between viewpoint and target, using the first reticle system (fig.14). The modern system for calculating the distance is laser rangefinder.

Looking at the above, further area of interest will remain thermal systems.

3. Construction and organization of thermal vision system

Initially electro-optic surveillance systems have been designed as independent systems (telescope, binoculars, rangefinder) (fig.15), mounted on weapons systems, or portable, able to be mounted on a tripod or military helmet, which could accomplish one function.

By upgrading electro-optic technology, was passed to digital systems that radically changed surveillance systems construction. Such systems are called modular systems (multisensory) built from existing electro-optic systems with specific functions. Their combined operation is ensured by careful assembly, made after a study of performance and compatibility.

Performances of interest of these systems are given by the characteristics of those values based on thermal sensors, which ensures competitiveness. Among the most important are reminded: wavelength; the distance of
observation (made up of the detection distance and the distance recognition); thermal resolution; geometric resolution; visual field; net weight.

In the case of optical sensors, with the increasing performance, increase overall dimensions and weight systems respectively. Therefore depending on the performance of sensors (fig. 16), were developed two types of modular surveillance optic sensors: short range and long-range modular systems.

![Figure 16. a) Thermal sensor for long-range systems, b) Thermal sensor for short range systems [4] [11].](image)

### 3.1. Short range modular systems.

Modular short range (digital) are designed as an observation equipment and acquisition targets, multipurpose, intelligent, portable with mass between 3-5 kg or mounted on a tripod, for surveillance of zones of interest, day, night and in difficult conditions environment, providing images and information about events observed perimeter.

The sensor in these systems can provide: observation and surveillance of the area of interest, day and night in difficult environmental conditions (fog, smoke); discovery of unknown targets, determinate the distance and calculation of absolute coordinates of targets; characterization of detected targets.

Such modular systems through good building can be organized in one or more subsystems (sensors) interchangeable, depending on their destination and user requirements (fig.17): daylight TV camera (1); thermal camera (2); laser rangefinder (3) (fig.18). Moreover there are intermediate components: ocular lens (4); global Positioning System – GPS; electronic block of analysis and conversation; battery; control buttons; laser marker.

![Figure 17. Short range modular systems [11] [21].](image)

![Figure 18. Optical sensors for short range systems [11].](image)
Daylight color TV camera is to observe the area of interest by day, and at night is filled by thermal camera provided with a video processing board. The electronic block of analysis and conversion, ensure integration of all systems components. Command buttons ensure the selection and performance of the system provided. Ocular design may be monocular or binocular organized through systems of lenses and color display that shows by switching images provided by both optical cameras. The ocular system can be fixed or removable, independent organized as a block, with the possibility to be mounted on a military helmet. The display can show different information overlaid the picture from the current camera. The same information can also be displayed on an external display connected to the video interface equipment.

3.2. Long-range modular systems

These systems can be considered as a feature of portable modular systems. These are characterized by a heavy duty construction with increased mechanical strength being, called sensors block (fig.19).

![Figure 19. Sensors block](image)

In order to be handled and accomplish the purpose for which they were designed, sensors block can be used as follows:

- **Independent** (fig.20): for surveying, observation of an area of interest day/night and in difficult environmental conditions and driving at night. The system can be operated remotely, can be mounted in fixed positions on the watch towers or mobile systems – special vehicles through mobile platforms stabilized;

- **A component part of a remote controlled weapon station** (fig. 21): Sensors block, which equips a weapon system, is to observe the battlefield during day and night. Over acquired image may overlap through Control Panel (CP), a stadiometry scale, with which to measure the distance to a target (or via a laser rangefinder - optional sensor block) or a reticle that allows the aiming and firing with the automatic weapons system. [13]
Through construction of the system is permitted to use the same sensors block in both configuration, which can be made from the following components (one or more sensors):

- Thermal imaging camera;
- Daylight TV camera;
- Laser Rangefinder;
- Control and interfacing board;
- Image processing board.

When using the sensors block independent, it formed into modern surveillance equipment organized on such systems:

- Optronic system (fig.23) formed by: sensors block; stabilized mobile platform; telescopic pillar (optional); GPS guidance system;
Data processing system (fig.24) formed by: computer system with display; operator Control Unit – OCU (control room located inside the vehicle);

Interconnect cables.

Stabilized mobile platform is designed to position the sensors block in the direction of the target, by rotating in the horizontal plane by an angle of 360° and vertical plan by an angle between a negative and other positive value (depending on system design), based on the commands received from the operator control unit (by joystick):

- Research battlefield horizontally and vertically;
- High speed movement on the two perpendicular axes;
- Precise positioning of the sensor block and auto tracking command;
- Targeting and range-targets through the sensor block;

4. Conclusion

In the design of obscurant smoke system, the first step is to identify the threat of any kind. Knowing the threat is the first factor that defines the requirements to develop a new system. As shown in this paper, the threat of daytime and night is described by modern electro-optic systems based on thermo vision that facilitates target detection and acquisition in adverse environmental conditions, which hinder masking performance. Such principles underlying observation systems will be input in shaping the new constructive solutions for countermeasure pyrotechnic system.
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