Acta Avionica
Volume XXIII, 45 – No. 2, 2021, DOI: 10.35116/aa.2021.0014

PERIMETER PROTECTION OF THE AREAS OF INTEREST

František HEŠKO*, Martin FIĽKO, Jozef NOVOTŇÁK, Patrik KAŠPER
Technical University of Košice, Faculty of Aeronautics, Rampová 7, 041 21 Košice, Slovak Republic
**Corresponding author.* E-mail: frantisek.hesko@tuke.sk

Abstract. This article analyses the history and current state in the area of outdoor protection. In the first part of the article, the sensory systems, which have been used for many years are described. Attention is paid to the sensors using conventional principles of the detection of the objects. New modern sensory systems together with their principles used for the protection of the outdoor environment are also described. Other problem is that older sensory systems of spatial protection were focused on the security of properties and buildings without expecting any change position in the time. The article analyzes also new possibilities of protecting of the outdoor perimeter even in the situations when the borders of the areas of interest are only temporary or mobile. And as UAV systems have been used massively and often involve modern multisensory systems, the last part of the article describes current sensors, which have been currently used to detect the UAV systems and to to protect the area of interest.

Keywords: outdoor space; perimeter; area of interest; detection; detectors; sensors

1. INTRODUCTION

Electronic protection of the area of interest has a significant meaning, and we increase attention in that way. A considerable threat from the side of security are substantial changes of possibilities to try attacks from intruders. Nowadays technologies provide better conditions for attempts of stealing, terroristic attacks, sabotages, or other attacks, the goal of which is destroying or damaging protected objects or people in that objects. The last few years, companies started using UAVs (Unmanned Aerial Vehicles), which have technological possibilities for the simple realization of many kinds of illegal activities like terroristic attacks, assassination, carrying contraband, or trespassing and others. Based on the above mentioned facts and entirely various commercial disponibility of the UAVs, we had to implement adequate actions. These actions forced to increase the standard requirements for the outdoor perimeter protection.

The main goal of the outdoor protection is to catch an intruder in a secured place with technical resources to prevent illegal activity. When we reveal intruders before trespassing into the area of interest, the security service has more time to react to eliminating the threat.

Solutions and installations of the systems of outdoor protection are very specific problems because creating adequate protection is impacted by the various conditions. These conditions are, for example, forecast, false alarm and other situations. We have to combine and integrate many different elements and methods, as in the case of the indoor environment.

We expect from devices and the systems for outdoor protection that they will work without a problem as the main priority. They have to be weatherproof. Sometimes, we can predict some weather conditions and eliminate their consequences. Often, we have to place them within easy reach of people and animals. Because it can cause many unexpected complications.

Quality sensorial and software equipment provides correct detection of disturbance of space without false alarm and failures. However, proper installation of outdoor protection has to be well designed and implemented to fulfil its purpose. Technological progress enables new ways to disrupt the protected target place. New systems and equipment could easily eliminate security systems. It is essential to stay current in researching and developing new security systems and sensors for outdoor protection. It is necessary to focus on this domain.

2. SECURITY SENSOR PRINCIPLES FOR THE OUTDOOR ENVIRONMENT

Various intrusion detection systems are used to secure a defined area of interest. According to the principle used to detect intrusion into the protected area, electronic perimeter protection devices are divided into two broad groups. These are overhead and underground systems.

Overhead systems use passive infrared detectors, microwave detectors, dual detectors, infrared barriers, microwave barriers, microphone cable, and fence-crossing detection systems. Fence-crossing detection systems use multiple principles, or methods, of intrusion detection. For example, electromechanical evaluation of mechanical wire tension, shock detectors placed on the fence mesh or a wall, evaluation of changes in the primary parameters of the detection cable, and others are used. The second group of outdoor protection are underground systems. These uses capacitive cable, microwave cable, unique cable systems, pressure hose and slotted cable to detect intrusions [1, 2].

Of the above detection systems, systems using infrared detectors, microwave detectors, microwave barriers and infrared barriers are still widely used today. The others are less and less widely used. The main factor is the complexity of the application and hence the cost per deployment. Also, in case of a failure, the repair is complicated, expensive and time-consuming. New systems are available on the market today. These perimeter protection systems will be introduced in the second part of the article [1, 2].

PIR (Passive InfraRed) detectors are still very attractive despite many years of use. Their advantage is their low price, ease of installation and reliability. PIR detectors evaluate changes in radiation in the infrared band of the electromagnetic wave spectrum. The sensing element is a gradient transducer (so called pyroelectric element). It means that, in principle, it cannot detect a constant level of radiation, but only changes in the radiation incident on the sensor. If in the field of view PIR detector moves a body with a temperature different from the ambient temperature, and the sensing element evaluates the changes and the connected electronics report that motion is occurring in the area of interest. Figure 1 shows 4 graphs of detection characteristics of PIR detectors with long (gray color) and short range (red color). Graphs on the left side of figure 1 show detection characteristics in the horizontal plane and graphs, and the right side has described these characteristics in the vertical plane. PIR detectors offer a different range of sensing characteristics with different ranges. The quality of PIR detectors has significantly increased (sensitivity, range, detection characteristics and others). Therefore, they are still very attractive and in demand in the market. An example of the use of different PIR detectors with different sensing characteristics are shown in Figure 2 [1, 2, 3].

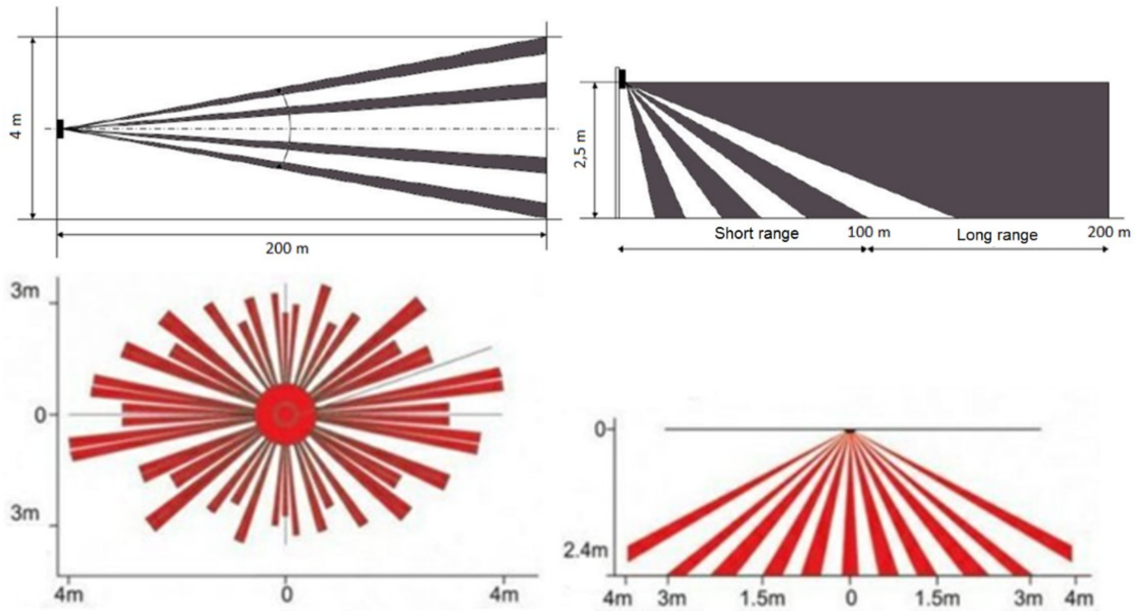
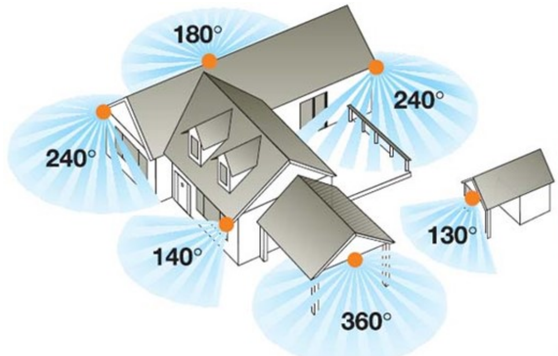


Figure 1 Detection characteristics of long and short range PIR detectors



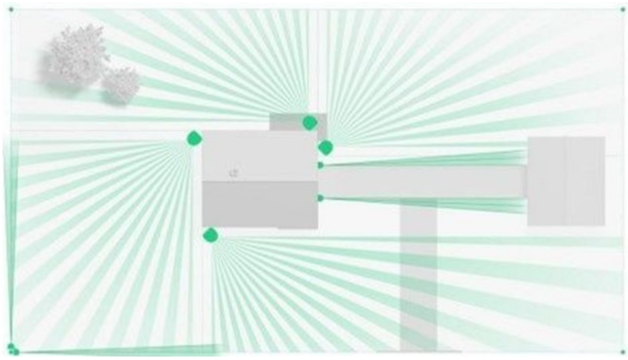
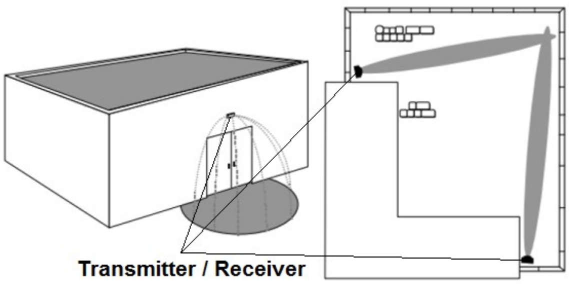


Figure 2 Example of application of PIR detectors with different sensing characteristics

Microwave motion detectors (MW), designed for the outdoor environment, emit a high-frequency signal (typically 10.525 GHz - the so-called X band) and evaluate changes in the signal reflected from the environment. The principle of operation uses the Doppler phenomenon, in which the frequency of the signal reflected from moving objects changes. The disadvantage of microwave detectors in general is the sensitivity to any movements in the field of view of the detector. In the outdoor environment, objects belonging to the protected area moving due to adverse weather conditions (wind, rain, snow) can cause false alarms. Therefore, MW detectors designed for the outdoor environment are usually equipped with additional circuits to protect against false alarms. These include close-up signal suppression circuits that limit the effects of rain, vibration, and wind-borne objects. Some detectors use a dual design to increase durability. Dual MW detectors use two receive channels. In order for an alarm to be triggered, the evaluation circuits monitoring both channels must detect a movement on the track of at least 20 cm. In addition, a signal processing mechanism is used. This mechanism eliminates weak signals, movement outside the set speed range and signals indicating bidirectional movement, which triggers false alarms caused by the movement of vegetation or small animals. An example of the introduction of microwave detectors is shown in Figure 3 on the left [1, 2, 4, 5].



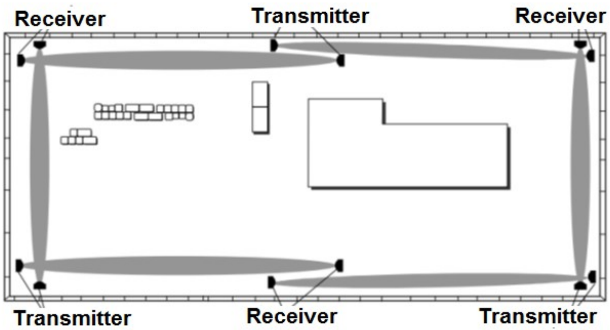


Figure 3 Application of MW detectors and MW barriers

If you need to guard the perimeter of a larger perimeter, it is advisable to use microwave barriers. Microwave barriers do not use the Doppler effect in their operation. The MW barrier uses the principle of evaluating the change in the signal received by the receiver. The change in amplitude of the received signal is directly proportional to the size and density of the target. Newer types of barriers operate in the 27 GHz frequency band (so-called T band), older ones use a frequency in the 24.125 GHz band (K band). Due to the fact that several barriers are used to protect the perimeter, it is necessary to ensure the resistance of the barriers to mutual influence. In practice, this is realized by modulating the transmitted frequency. For example, modulation frequencies of 3 kHz, 4.5 kHz, 7.5 kHz and 10.5 kHz are used. Figure 3 on the right shows an example of the installation of MW barriers and Figure 4 shows a 3D visualization of the detection characteristic around the perimeter of the protected space. For such protection, it is necessary to use 4 MW barriers, which contain 4 MW receivers and 4 MW transmitters [1, 2, 4, 5].

Figure 4 3D visualization of MW barrier characteristics

An infrared (IR) barrier is a detection device that triggers an alarm condition in response to an interruption of the infrared beam between the transmitter and receiver. The infrared barrier is created by applying an optical sensor. Optical sensors generally respond to light, or to the difference in brightness of the light beam that strikes the optical sensor. An example of the use of the infrared barrier is shown in Figure 5, where there is also a detailed view of the optoelectronic sensor and the IR barrier transmitter, respectively [4, 5].

Figure 5 Example of using an IR barrier with a detailed view of an optoelectronic sensor / transmitter

3. MODERN WAYS TO PROTECT THE OUTDOOR SPACE

A camera system is a part of almost every security in the areas of interest. The above-mentioned older detection systems were in most cases supplemented by a camera system. However, they did not serve to detect the intruder. They performed the task of continuous surveillance of the protected area for the security service. In the event of a breach, the above systems have notified the security service. They could immediately look at the place of violation through the camera system and, based on that, adequately intervene or evaluate a false alarm. CCTV systems are still widely used a direct visual surveillance of the protected area, where continuous monitoring is required [1, 2].

Today we know cameras that are at a higher technological level and some of them have the possibility of various functions. Today, camera systems are commonly used as a stand-alone intrusion detection system. They can detect space distortion from the captured image and highlight it on the display unit. Some smart camera systems can alert suspects. An example of such detection is shown in Figure 8 on the left. Some camera systems can even detect any movement, mark movement points on the display unit and analyze the object (human, animal, car, vegetation, objects carried by the wind, birds, unmanned aircraft, etc.). They are camera systems with a certain level of artificial intelligence. There are camera systems with the ability to learn. These are not yet used in practice for spatial protection.

The quality of the cameras has increased many times in recent years. Due to the competitive struggle, the price of the cameras is falling despite the growing quality. Nowadays, ordinary people can afford quality camera systems. The big disadvantage of intelligent space protection camera systems is that they cannot work reliably in poorer visible conditions. Another problem is when the intruder merges with the background. Thermal cameras or other systems working on a different physical principle are used to protect areas where visual conditions are worse.

Due to the high price, thermal imagers have long been used only in the military and in special applications in industry. Today, their quality is high at a relatively low price. Therefore, the use of thermal imagers in the commercial sphere is constantly growing. Thermal imagers are of great importance in protecting areas of interest with poorer visual conditions. They make it possible to reliably monitor the area of interest at night, in a smoky area, in dusty conditions and in worse meteorological conditions. Figure 6 compares the images of a conventional camera (left) and a thermal imager (right). In the upper part of Figure 6, a foggy or smoky environment is simulated. At the bottom of Figure 6 are images of the protected area at night. It can be seen that the use of a thermal imager multiplies the possibility of detecting a potential intruder in poor visual conditions [6].

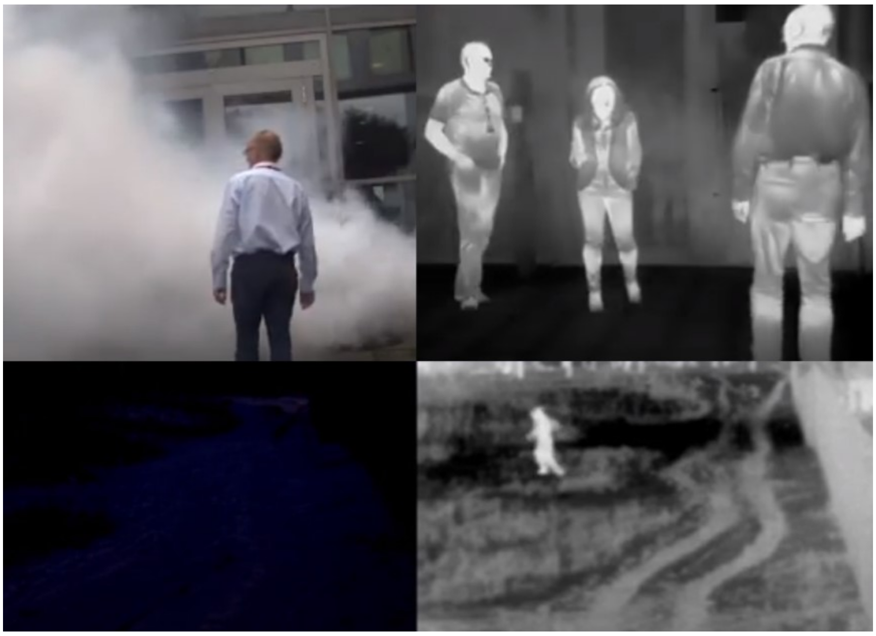


Figure 6 Footage of an ordinary camera and thermal imager in worse visual conditions

The thermal imager consists of infrared radiation sensors or radiant thermal energy sensors. These sensors are not sensitive to visible light, which makes us see very well in poor lighting conditions. This is because they sense infrared radiation emitted by the observed objects. The energy captured by the sensors is converted into an image that shows the energy differences between the scanned objects. Infrared light reveals characteristics that are not recognizable under visible light. For this reason, even in complete darkness, it is possible to observe the outline of humans, animals, mobile devices and the like.

In critical areas of industry, it is possible to monitor heat leaks or high voltage lines, where it is possible to identify the extent of damage or detect an impending fault with the help of a thermal imager. Subsequently, it is possible to take all measures in time to prevent huge damage.

In the current situation, when we have big problems with Covid-19 in the world, an intelligent system consisting of a camera and a thermal imager can be very useful. We currently have the Sunview system on the market. This system can automatically identify and alert people to high temperatures. The Sunview system integrates a thermal temperature camera and a standard camera in one device. This system works reliably in public places as a preventive measure against the rapid spread of infectious diseases, the symptoms of which are fever. A typical place for installation can be spaces through which an increased number of people pass. This system can be easily applied to airports, bus and train stations, shopping centers, schools, kindergartens, banks, hotels, restaurants and more. Figure 7 shows a smart camera, how to evaluate it and display the observed area. It is clear from this view that it is a system with a certain level of intelligence. The system can recognize faces and assign a measured temperature value to a given face. In the case of a measured elevated temperature, it notifies the authorized person and distinguishes this person in color on the display unit with the corresponding measured temperature value. This system can distinguish up to 16 people at a time. The camera system is marked ZN-T1 and is manufactured by ZKCeco. The sensed temperature range is from -20 °C to 60 °C, the response time is 50 ms and the measurement accuracy is up to 0.3 °C [6].

Figure 7 Visualization of Sunview system and ZN-T1 camera system

Technological progress has not bypassed radar systems, which are very common today and used in ordinary society. Radar systems have been used in the past mainly in the military, aviation, shipping, and possibly in the police and metrology. Today, radars are commonly used in the automotive industry, rescue services, to protect and monitor areas of interest. The use of radar is a very practical solution for demanding terrain and climatic conditions. Radars help save lives in the mountains or densely wooded areas. The combination with an HD camera reduces the time required to recognize a person by 95 %. The radar determines with sufficient accuracy where to focus the camera's attention significantly before an experienced observer notices movement in the image. The radar detects just as effectively during the day and night. Figure 8 shows the motion detection time of a quality camera system (left) and a radar system (right). In the middle upper part of Figure 8, the SpotterRF SP-C1050 radar for locating moving objects, which was used for this purpose, is shown. The experiment proves that the radar system detected the intruder much earlier than the camera system [5].

The operating frequency of the radar is 10 GHz. The area covered by the detection signal is 1400 m x 1100 m. The radar can independently monitor up to 30 moving objects. The angles of the detection characteristic are in the horizontal plane of 90° and in the vertical plane of 20°. The perimeter scan is 8 times per second and the radar operating temperature is from -40 °C to 60 °C [5].

There are currently a number of radars on the market with various parameters such as the size of the monitored perimeter, detection characteristics, the number of monitored objects and others. Radars have been used in the past mainly to protect the perimeter of larger ranges. Today, manufacturers also offer radars with a small protective perimeter, such as the SpotterRF SP-CK2 radar. This radar offers a protective perimeter in the horizontal plane (125 x 40) m. Such a radar is an ideal solution for securing space around small companies, lands of small farmers, used cars and the like [5].

Figure 8 Comparison of camera and radar system intrusion detection

A very interesting detection method that has been used to protect the perimeter is with LiDAR (Light Detection And Ranging). LiDAR measures distances based on the calculation of the pulse propagation time of the laser beam reflected from the scanned object, which is evaluated in the photodetector. The distance of the LiDAR object is calculated as half the time that elapses between the transmission and the laser pulse. The result of the mapping of the terrain or space by LiDAR is a so-called point cloud, which is processed using algorithms and interpolated to create a 3D digital model of the surface of objects in the field of view. By further processing and filtering, a digital terrain or space model can be created from the points. Such an image created using LiDAR is shown in Figure 9. Instruments working with this technology are used in both ground and aeronautical applications [7].

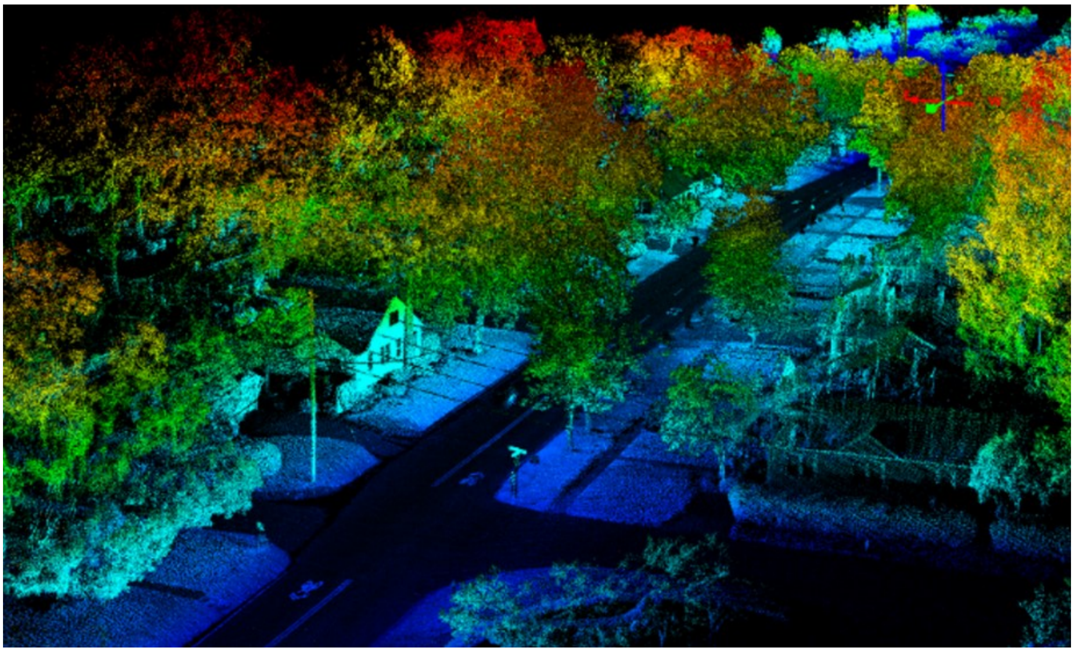


Figure 9 3D visualization created with the help of LiDAR

The advantage of Lidar in the monitored area of interest is that it works the same in complete darkness. Quality LiDARs work reliably even in worse meteorological conditions. LiDAR makes it possible to precisely determine the distance of the intruder, or to ensure its tracking. Space protection can be provided by 2D or 3D LiDARs. 2D LiDAR, compared to 3D LiDAR, provides a simpler and cheaper alternative to protect the area of interest. In this case, LiDAR alerts you to the location of the disturbance without 3D visualization of the space. There are many LiDAR manufacturers on the market today that offers a variety of design solutions. Figure 10 shows several examples of different design solutions of relatively simple LiDARs used to protect the area of interest [7, 8].

The first from the left is 2D-LiDAR LMC1xx. It measures in the range from 0.5 m to 20 m. The working angle in the scanning plane is 270° and the scattering angle is from 0.25° to 0.5°. The scanning frequency is 50 Hz and the operating temperature is from -30 °C to 50 °C [9].

The second discount is the 3D LiDAR MRS6000. The working angle in the horizontal plane is 120° and in the vertical plane is 15°. It is able to provide scanning reliably up to 75 m and can provide distance measurement in the range from 0.5 m to 200 m. The scanning frequency is 10 Hz and the operating temperature is from -20 °C to 60 °C [9].

Third in line is the 3D LiDAR LR-16F. It scans 360° in the horizontal plane and from -15° to 15° in the vertical plane. Detection is provided up to 100 m, operating frequency is 20 Hz and operating temperature from -10 °C to 50 °C [9].

The fourth is the 3D-LiDAR MRS1000. The range of the sensed distance is from 0.2 m to 64 m. The scanning angle in the horizontal plane is 270° and the angle in the vertical plane is 7.5°. The scanning frequency is 50 Hz and the operating temperature is from -30 °C to 50 °C [9].

The last in line is the 3D LiDAR LD-MRS. The horizontal scanning plane is variable from 25° to 110° and the vertical plane is 3.2° or 6.4°. The working area of the measured distance is from 0.5 m to 300 m. The scanning range is up to 150 m and the working temperature is from -40 °C to 70 °C [9].

Figure 10 Example of LiDARs used to protect space

4. SPECIAL MODERN WAYS TO ENSURE THE OUTDOOR PERIMETER

Many authors focus on securing the stationary perimeter when protecting the outer perimeter. However, it is a common practice today to secure also a moving perimeter. It is mainly used in the automotive industry. Today's modern cars create a certain protective perimeter in their surroundings. They use ultrasonic sensors, radars, LiDAR, cameras and others to do this. The example of such a comprehensive perimeter protection of a passenger car is shown in Figure 11 [7, 8].

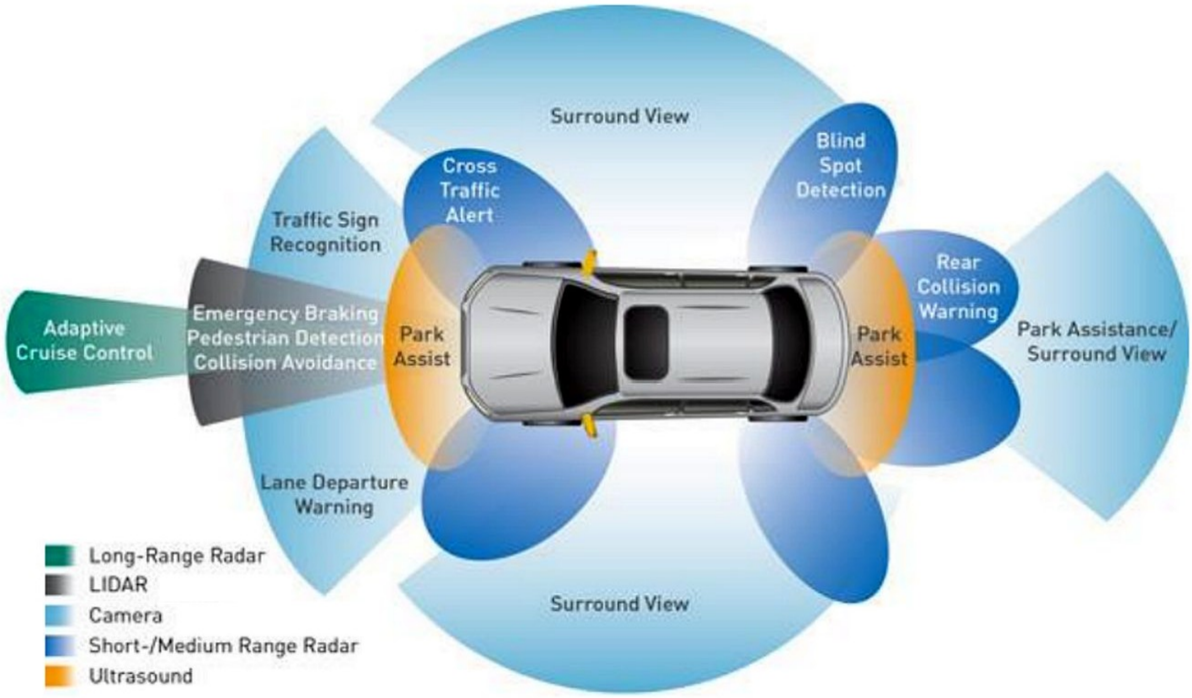


Figure 11 An example of a complex protective exterior perimeter of a vehicle

Based on the data captured from the sensors used, cars can warn or react to pedestrians, animals and other obstacles. Figure 12 is an experiment showing a comparison of the LiDAR image display (left) and the camera (right). It is a view of the perimeter in front of the car while driving in the city at night. An ordinary camera and human eye are not able to detect a potential threat such as a person standing on the side of the road. This person is clearly visible on the LiDAR record. We can also notice that LiDAR also scans the lines on the road, which testifies to its high sensitivity and accuracy. [7, 8].

Figure 12 Recording from a night drive from a LiDAR and a camera

LiDAR offers a new approach to perimeter protection. It is becoming increasingly important, especially in road transport. LiDAR offers cars while driving to create a mobile protective perimeter in real time, which protects or maintains surveillance around the vehicle (eg maintaining a certain distance from the vehicle, obstacle warning, etc.). An example of using LiDAR on a car is shown in Figure 13. It should be emphasized that the 3D visualization of the space from LiDAR, which is shown in Figure 12 (left), is not displayed in cars, but the scanned data is for car assistance systems. [7, 8].

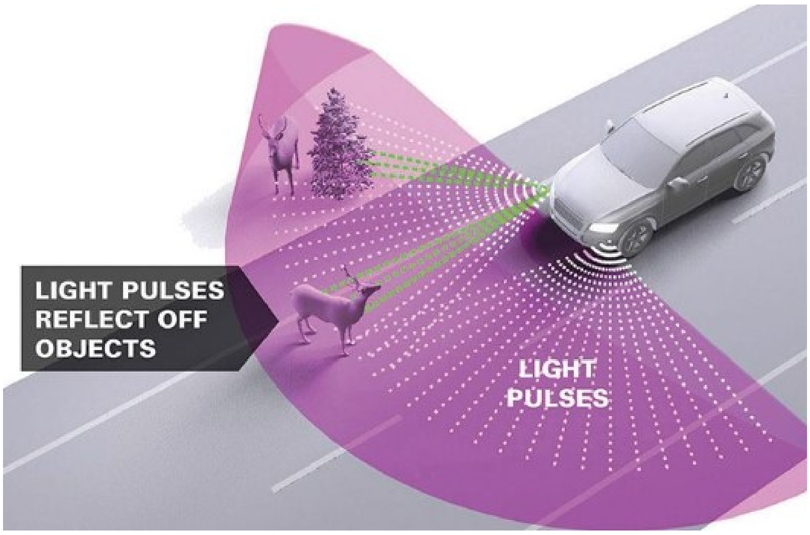


Figure 13 Protective moving perimeter in front of the car using LiDAR

Ultrasound sensors have been used for several years to protect the mobile perimeter, especially in the automotive industry. These are still used as parking sensors. Ultrasonic sensors are among the active elements. The transmitting part emits a constant high-frequency wave into space, which is not audible to the human ear. The receiving part receives the reflected wave and evaluates the changes in its frequency and phase that occur when the body moves in the protected space. This is an application of the Doppler effect in the ultrasonic frequency band. The advantages of these detectors are small size, low cost and the ability to work in poor visual conditions. Ultrasonic motion sensors are used to monitor a smaller perimeter, on the order of several tens of meters. Animals with sensitive hearing (eg dogs) can react sensitively to the presence of ultrasound, therefore ultrasonic detectors with a working frequency of 40 kHz or 60 kHz are used [7, 8].

Perimeter protection of mobile devices has been known in the military for several decades. Mobile perimeter protection is commonly used on battleships, submarines, tanks and the like. Significant advances in electronics have enabled a higher level of electronic warfare. Therefore, the demands on perimeter protection are becoming increasingly important. The arrival of unmanned aircrafts, especially those that fly, has brought even greater interest in protecting the outer perimeter. Demands for perimeter protection have increased significantly in the military. Current unmanned systems pose a great danger in terms of disruption of the area of interest. Therefore, various multisensor systems began to emerge to protect the perimeter primarily against UAS (Unmanned Aerial Systems. These systems have a common name for anti-UAS systems and were first used in the military [10]. However, the protection against UAVs have become a very discussed topic also regarding the security of airports because UAVs represent a threat for the aircraft especially during the take off and landing.

Figure 14 on the right shows a military terrain vehicle equipped with a modular electrical system to protect the mobile perimeter. This system is designed and manufactured by the Israeli company RADA. It consists of MHR (Multi-Mission Hemispheric Radar) and omnidirectional jammers. The radars and the jammer are located in a fixed column. On the telescopic pole are located: a quality camera for the visible spectrum, a camera with night vision and a thermal camera. One MHR-type radar platform provides reliable azimuth and elevation coverage in the 90 ° range. Four MHR radar platforms must be used to cover the 360 ° azimuth in the horizon. The reported range of the RPS-42 radar is 30 km. The company also offers more powerful MHR radar platforms, which have many times higher range. There are also radar platforms as shown in Figure 14 on the left, which have a coverage of 120 ° in the horizontal plane. The advantage is that only 3 platforms are needed to cover the 360 ° perimeter instead of 4 platforms [10].

Figure 14 Military vehicles with external perimeter protection systems

In addition to stationary perimeter protection, temporary perimeter protection has been used in the military for many years. RADA allows the use of these mobile perimeter protection sensor systems for temporary perimeter protection. In this case, the sensor systems are placed on special portable poles, see Figure 15. The system is modular, which allows fast installation and operation in a very short time. This makes it possible to quickly create a protective perimeter anywhere in the field. The soldiers can then safely perform the necessary activities in the area and, after performing the necessary tasks, quickly dismantle the system and leave the area. The introduction of a temporary protection area allows continuous monitoring of the environment. Such a system can alert you to a potential threat over time, locate it, identify it, monitor it and, if necessary, put the defense systems into operation, either automatically or at the request of an authorized person [10].

The reason why the manufacturer designed such a multisensor system is that MHR radars have their operating limitations. They are not able to correctly evaluate a flying target that is moving at a speed of less than 9 km/h, or is flying at an altitude of less than 9 m or if it is closer than 150 m from the radar. To increase the reliability of protective perimeter detection, these radars are complemented by an EO (Electro-Optical) sensor (camera), an IR (Infra-Red) sensor (thermal imager) and an RF (Radio Frequency) sensor. Directional or omnidirectional jammers, which serve as a defense against UAS, are also a common part. Figure 15 on the left shows a system from Rafael Advanced Defense Systems called the UAV Dome. In the middle is the RADA system and it is called RSK-55 and on the right is the visualization of this system when disturbed by a quadcopter [10].

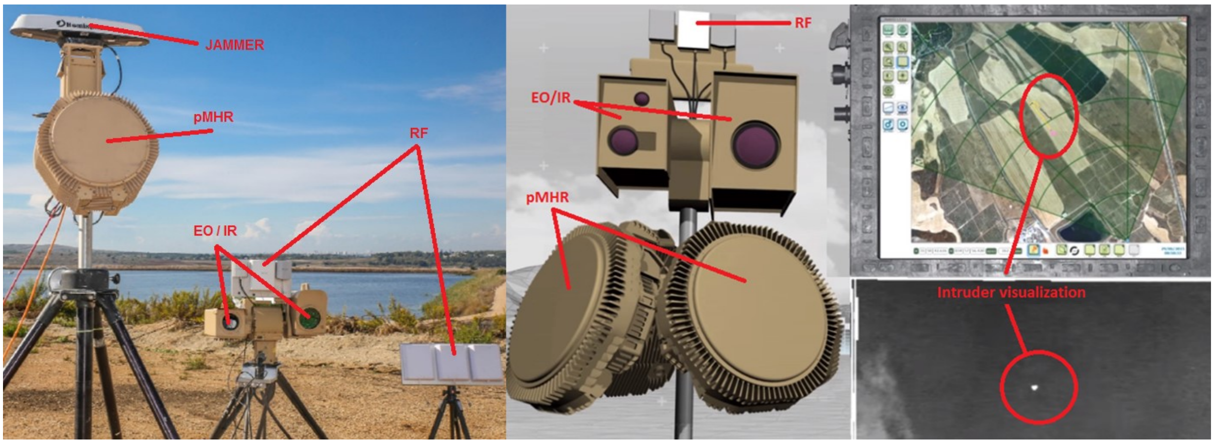


Figure 15 Method of temporary perimeter protection

In the civilian sphere, perimeter protection has also been extended to include protection against UAS. Much attention has been paid to this area in recent years. The number of different incidents that cause unauthorized UAS is growing. In order to increase the detection capability and prevent false alarms, the use of multisensor systems is a trend today. In principle, these systems are similar to military ones. An example is shown in Figure 16 left. This system is designed by Droneshield. It can be seen that this company offers multisensor detection systems similar to the Council.

Acoustic sensors have also started to be used today, mainly due to UAS intruders. The American company Droneshield provides a high-quality solution in this area. Figure 16 on the right shows acoustic sensors that can detect even small UASs for several kilometers. Droneshield differs from the others in that their acoustic sensors can detect small UAS up to several hundred meters. In good conditions, even a few kilometers. Other manufacturers on the market, which have an acoustic detection system, can detect small UAS at about 100 m, maximum 200 m [10].

Figure 16 Modular external perimeter protection system and acoustic sensors

Today's outer perimeter protection systems usually have different functions. These are, for example, detection, localization, monitoring, warning, visualization of the security perimeter, visualization of the intruder and storage of the record in memory. Some systems are also equipped with a defense system, ie they have a defensive function. The defensive function is used in case of UAS breach, when the system is equipped with a jammer that prevents the intruder. The most important part of these systems is the sensor system. Particular attention is paid to the sensor system, because without proper detection, other system functions would be unnecessary. The sensor system must also reliably detect small UAVs, Figure 15 (left). We see that the system can detect a small multicopter, can locate it, monitor it and informs the security statement about everything, where it also provides a visualization of the intruder [10].

A very interesting company that came to market with a new anti-UAV system is Aaronia based in Germany. Aaronia has developed a high quality Aartos anti-UAV system (Fig. 17). It consists of high quality IsoLog 3D broadband monitoring antennas, which consist of 8 or 16 sectors. They operate in the range from 9 kHz to 20 GHz. This detection system also includes a high-quality Spectran V5 spectrum analyzer and a jamming system. The uniqueness is that it can capture the various signals it generates during a UAS flight. This system can be used for both stationary and temporary space protection. As can be seen in Figure 17, the company also offers a transport trolley for more convenient transport and quick delivery to the required location. In addition to detecting the UAS, determining its location and tracking, it can also determine the location of the operator. Therefore, the security service can also intercept the operator and thus prevent further attempts to disrupt the space [10].

Figure 17 Artos system from Aronia

5. CONCLUSION

Increasing attention is being paid to the protection of areas of interest. In the past, security systems for spatial protection were concentrated mainly on the boundaries or the perimeter of the area of interest. These were fencing breach systems or underground systems located around the perimeter of the secured or protected area. Today, such security and protection systems are insufficient. The nature of the attacks is increasingly complex in terms of detection, so the demands on the spatial security have been increasing. Based on these facts, better perimeter security systems have been developed. Some of them are replacing older detection systems. Advances in sensors, electronics and artificial intelligence also make a significant contribution to the development of new and better detection systems. Today's systems focus not only on borders, but also on the entire interior space. They even provide the ability to monitor the area beyond the protective perimeter. This makes it possible to detect a potential threat before it enters the protected perimeter.

Furthermore, it should be noted that the protective perimeter can be stationary, temporary or mobile. Temporary and mobile perimeter security and/or protection has been known in the military for several years. In particular, mobile perimeter protection is used more frequently in the military on ships, submarines, tanks and special military vehicles. In the civilian sphere, the interest in the security and protection of the mobile and temporary perimeter has only begun to show significantly in recent years. Today, mobile perimeter protection is used mainly in modern cars. Every car that is capable of perimeter protection must have sensory equipment for this purpose. Today, ultrasonic sensors, radars, LiDar and camera systems are used. Modern intelligent cars create a safe perimeter in their surroundings, which is constantly monitored. In the event of danger, the system can warn or decide and react on its own, thus increasing the safety of the car traffic.

In the second decade of the 21st century, unmanned aerial vehicles began to be widely used in mainstream society. This causes various illegal incidents to increase each year, exploiting the technical capabilities of the UAS. This fact prompted the manufacturer of detection systems to develop better quality sensor systems with new detection methods and to start with the production of UAS detection systems, so-called anti-UAS systems. They usually use intelligent camera systems or so-called electro-optical sensors, IR sensors (thermal cameras), radar systems of smaller ranges (range of hundreds of meters to several kilometers). Furthermore, various MW and RF detectors, acoustic sensors, LiDAR-i, ultrasonic sensors with a longer range are used. Manufacturers use multiple sensors at the same time to enhance the capabilities of the anti-UAS systems. They work on different physical principles.

Today, there is a trend to produce multisensor modular systems that the user can easily assemble according to their own needs. Multisensor systems are used to prevent false alarms in harsh conditions and to increase detection capabilities. Also, in case of a failure of some sensors, the security system is able to continue working and to provide a certain degree of reliable detection. Manufacturers are introducing the ability to connect with smartphones. In this way, it is possible to ensure the immediate submission of information about the violation, even with the visualization of the violation. The system can notify security components in parallel. This supports a timely response and consequent rapid and effective disposal of the intruder.

In conclusion, it can be stated that the number of incidents of disruption of areas of interest is increasing from year to year. As well as the nature of the attack, as intruders have better access to today's technical gains. For this reason, the development of external perimeter security and protection systems will have to constantly develop and improve.

Acknowledgement

This work was supported by the project Mobile Monitoring System for the Protection of Isolated and Vulnerable Population Groups against Spread of Viral Diseases, ITMS code 313011AUP1, co-funded by the European Regional Development Fund under the Operational Programme Integrated Infrastructure.

References

[1] Veľas, A. *Elektrické zabezpečovacie systémy.* Žilina: University of Žilina. 2010. 104 p.
[2] Pavlů, M. *Detektory pohybu.* Praha: University of Regional Development and Banking Institute. 2019. 71 p.
[3] *Motion Protect Outdoor.* AJAX Official partner. 2020. Available at: https://best-alarm-system-webshop.eu/de/produkte/ajax-motionprotect-outdoor/
[4] *Mikrovlnné bariéry a detektory.* Sup companies. 2012. Available at: http://www.supkn.sk/specialne-sluzby/
[5] *Perimetrická ochrana.* TSS GROUP. 2021. Available at: https://www.tssgroup.sk/produkty/zabezpecenie-objektov/perimetricka-ochrana
[6] *Riešenie merania teploty.* JH services. 2021. Available at: https://jhservices.sk/2020/03/18/riesenie-merania-teploty/
[7] *Moderní použití Lidaru nejen v oblasti bezpečnosti.* Linked in. 2021. Available at: https://cz.linkedin.com/pulse/modern%C3%AD-pou%C5%BEit%C3%AD-lidaru-nejen-v-oblasti-bezpe%C4%8Dnosti-vladimir-nov%C3%A1k-1e
[8] *Čo je to LiDAR?. Nielen vylepšený „zrak“ pre autonómne autá.* Techbox. 2020. Available at: https://techbox.dennikn.sk/temy/co-je-to-lidar-nielen-vylepseny-zrak-pre-autonomne-auta/
[9] *Produktové portfolio.* Sick Sensor Intelligence. 2021. Available at: https://www.sick.com/sk/cs/c/products#g91899
[10] Heško, F. *Multisenzorový system pre detekciu UAV.* Košice: Technical university of Košice. 2019. 113 p.

Received 12, 2021, accepted 12, 2021