EXPERIMENTAL TESTING OF PASSIVE INFRARED DETECTORS AND EXAMINING THE PROBABILITY OF INTRUDER DETECTION

Michal Peňaška[1], **Milan Kutaj**[2]

Abstract: The article describes intruder alarm systems, experimental testing of selected components of these systems, and examining the probability of intruder detection in a protected area. Component parameters are specified in the producer technical documentation (datasheets, service manuals) and they have to comply with European technical standards. Specifically, the article focuses on passive infrared motion detectors, which are among the most used components of intruder alarm systems. Experiments were carried out under the conditions specified in the European technical standards and also beyond these conditions. The experiments were performed in controlled measuring and testing laboratories. The results of the experiments can be used as a basis for improving the European technical standards, a proposal for their modification, and also for the evaluation of intruder alarm systems.

Introduction

Intruder alarm systems are part of the active elements of physical protection systems. An intruder alarm system consists of certain types of components. Each component has its uniquefunction in this system and each component is used to detect a particular type of intrusion. The intruder alarm system is one of four parts of a security system which is designed to detect, and if it's possible, to identify an intruder. Due to the increasing availability of intruder alarm systems and their increasing complexity, it is appropriate to test the reliability of individual components of intruder alarm systems.

Passive infrared detectors

Passive infrared motion detectors, also known as PIR detectors, have an irreplaceable role in intruder alarm systems (Garcia, 2006; Hofreiter & Krížovský, 2017; Lovecek et al., 2016). All objects emit some amount of infrared radiation (heat) into the environment. The intensity emitted by certain objects such as the sun is easily detectable, but the intensity emitted by the human body is almost negligible (Honey, 2007; Michalec, 2013). The heat emitted into the environment is specific to each object and depends on its chemical and physical composition and temperature (Buchanan, 2004; Loveček et al., 2015; Velas, 2010). The human body radiates infrared radiation with a wavelength of 8 - 14 μm, which is invisible to the human eye. Infrared motion detectors are used to detect infrared radiation at a given wavelength range (Křeček, 2006; Loveček et al., 2015; Medjdoub, 2017).

Figure 1: Block diagram of PIR detector

Source: authors
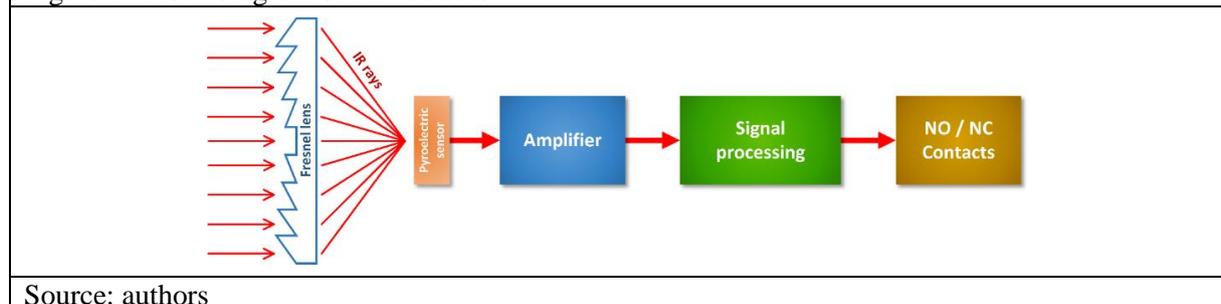
Passive infrared motion detectors (PIR detectors) are designed to effectively detect changes in infrared radiation in the environment and generate a corresponding electrical signal. The PIR detector consists of three basic parts:

- system of segmented mirrors or a Fresnel lens,
- sensor – a pyroelement chip, which generates electrical signals depending on the intensity of the infrared radiation,
- mainboard with electronics used to amplifying electrical signals generated by the pyroelement chip and terminal outputs for wiring harness(Loveček, et al., 2015; Velas, 2010).

[1] Michal Peňaška, Faculty of Security Engineering, University of Žilina, Slovakia, michal.penaska@fbi.uniza.sk
[2] Milan Kutaj, Faculty of Security Engineering, University of Žilina, Slovakia, milan.kutaj@fbi.uniza.sk

The image of the secured area is projected onto the surface of the sensor through the lens. The field of view of the detector is divided into active and inactive zones, which we can imagine as visible and covered parts of the image of the secured area. The movement of the body whose temperature is different from the room temperature, is captured by the detector in the transitions from the inactive to the active zones and vice versa. The electronics then evaluates the signal that causes these changes and trigger an alarm(Křeček, 2006; Velas, 2010; Velas, 2013).

Figure 2:The field of view split into individual zones
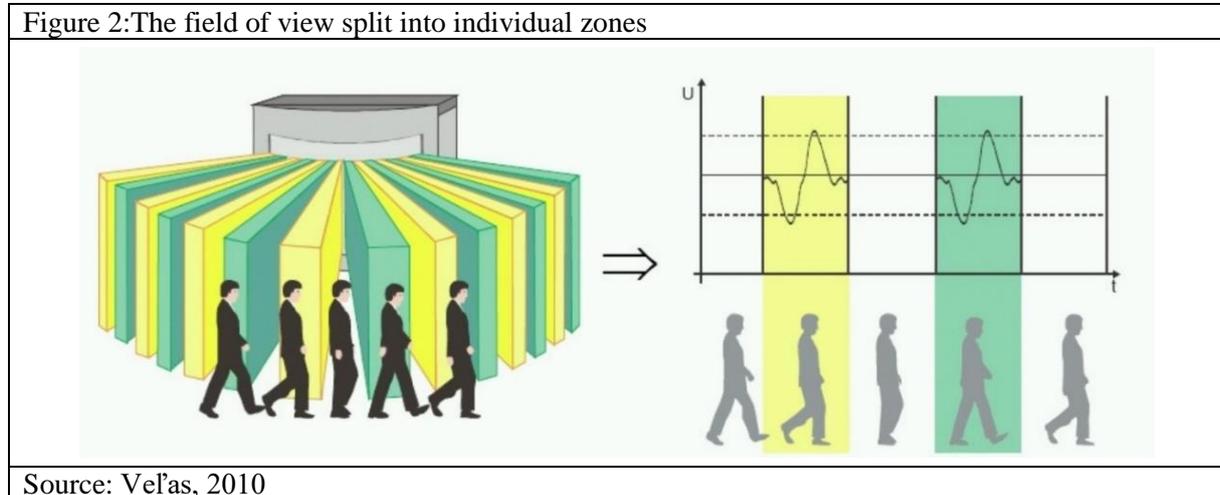
Source: Veľas, 2010

The success rate of manufacturers in deploying new technologies can be determined either by conducting a customer satisfaction survey or by experimental testing of the components themselves. Experimental testing is currently being done by researchers and students of the Department of Security Management of the Faculty of Security Engineering. Over the last years, they have been performed a large number tests of passive infrared detectors (including MW / US), magnetic contacts, vibration detectors, glass break detectors, wireless elements and so on.

Previous results indicate that some components do not meet the security level requirements and can be overcome in several ways. Of course, the results cannot be generalized on a sample of a limited number of detectors.

Probability of intruder detection

The intruder crosses the individual detection zones on the way to accessing a protected object (Garcia, 2006; Lovecek, Velas, Kampova, Maris, & Mozer, 2013; Svetlik & Velas, 2016). If this is an active detection zone, the intruder will be detected with some probability P_{Di}, which will then trigger the alarm. The detection zones through which the offender passes from the perimeter to the protected object do not have the same probability of detection. For this reason, we are talking about the cumulative probability of intruder detection P_{KDET}, which is expressed by relation (1) (Lovecek, et al., 2013).

$$P_{KDET} = [1 - \prod_{i=1}^{n}(1 - P_{Di})] \times P_{PPS} \times P_P \times P_{LF} , \qquad (1)$$

where:

P_{KDET} —   cumulative probability of intruder detection,

n —   number of detection zones during intruder's path,

P_{Di} —   the probability of proper detection by an active element (e.g., a PIR detector) in the detection zone during an intruder's path,

P_P —   probability of failure-free status of the intruder alarm system,

P_{PPS} —   probability of transmitting the alarm signal over the alarm transmission path to the remote alarm receiving centre,

P_{LF} —   probability of reliability of the human factor (Lovecek, et al., 2013).

The most common components used in intruder alarm systems are passive infrared detectors (Mokrý, 2018). The detection characteristic is specified by the manufacturer in the technical documentation,

and its shape and size depend on the used lens and pyroelement chip. The probability of intruder detection can be calculated by the relationship (2) (Lovecek, et al., 2013).

$$P_{Di} = \frac{S_{Zi}}{S_{FPi}} \times P_{DvOi} , \quad (2)$$

where:

P_{Di} — probability of intruder detection by the intruder alarm system in the i-th detection zone during his path,

S_{Zi} — detector characteristics in the i-th detection zone [m²],

S_{FPi} — the total area of the i-th detection zone [m²],

P_{DvOi} — probability of intruder detection on detector characteristics in the i-th detection zone (Lovecek, et al., 2013).

In the case of PIR detectors, the probability of intruder detection in the detection zone is normally equal to one ($P_{DvOi} = 1$) (Velas, Kutaj, & Durovec, 2017).

If the intruder is ready to overcome the electrical security system, the probability of intruder detection in the detection zone decreases. This decrease depends on a number of factors and cannot be calculated without obtaining a large amount of data. It must be determined by experimental tests and measurements. After experimental testing of PIR detectors, it is possible to perform a detailed analysis. Based on the results of this analysis, it is possible to find relationships that would determine the probability of intruder detection in the detection zone.

Experimental testing of PIR detector Guardall DT15

During experimental testing, a person 1.60 - 1.85 m high and weighing 70 kg ± 10 kg (STN EN 50121-2-2) was used as the standard detection target. The standard defines that the detection target must be dressed in suitable tight clothing and must emit at least 80% in the wavelength range of 8-14 μm. All requirements specified in the standard were met during the tests. The tested PIR detector Guardall DT15 was mounted on a metal tripod and installed at a height of 2,3 m. The Yihua HY-1503D laboratory source was used to power the PIR detector(Kucera & Sebok, 2012).

Standard STN EN 50131-2-2 describes the method of verifying the boundary of the detection characteristics. It is only a possible method of verification. Manufacturers, lab workers, researchers, and others have the opportunity to develop their own methods and procedures for verifying detection characteristics.

In the measuring and testing laboratories a square grid with points spaced 1 m apartwas formed. Verification of the detection characteristic was performed perpendicularly to the PIR detector axis. Movement began at a distance of 1 meter in the detector axis. Each boundary point of the detection characteristic was verified 10 times. The PIR detector passed the test if a maximum of 2 attempts were wrong. The process of verifying the boundary of detection characteristics is schematically illustrated in Figure 3.

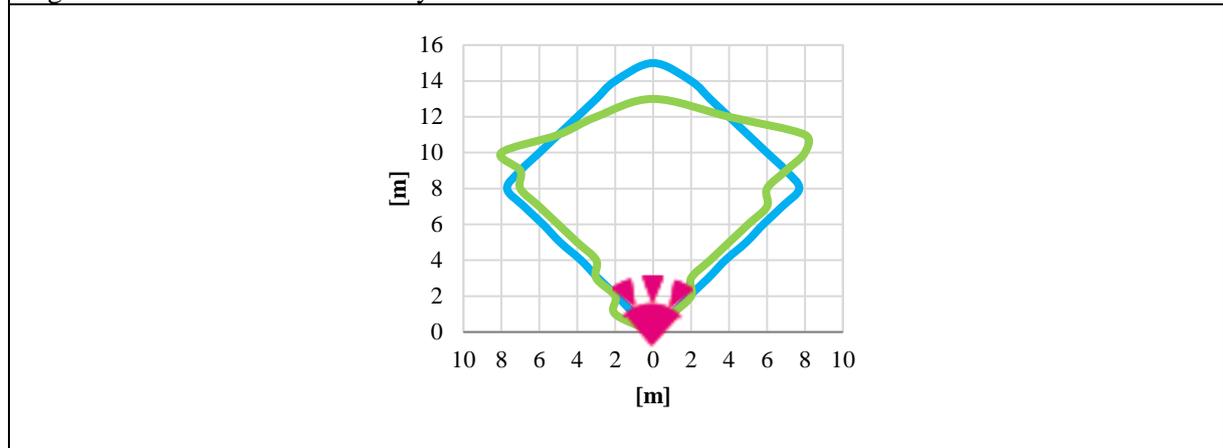Figure 3: Verification of boundary of detection characteristic
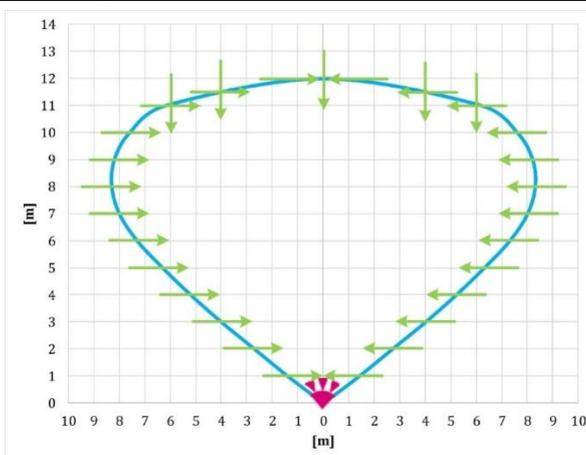
Source: authors

The experimental testing has revealed a precise detection characteristic that is way different from the characteristics described in the service manual provided by the manufacturer (e.g. the detection characteristic does not have a regular shape).

Detection characteristic of Guardall DT15

Comparison of the detection characteristics of the Guardall DT15 PIR detector is demonstrated in Figure 4. According to the manufacturer, the detector should detect movement up to a distance of 15 meters. After testing, it was found that the maximum detection distance is only up to 13 meters. The differences between the described and the measured detection characteristic are noticeable on the both the left and right side. The biggest differences are in the corners of the detection characteristic. The characteristic is wider by up to 2 meters compared to the manufacturer's specifications in the service manual.

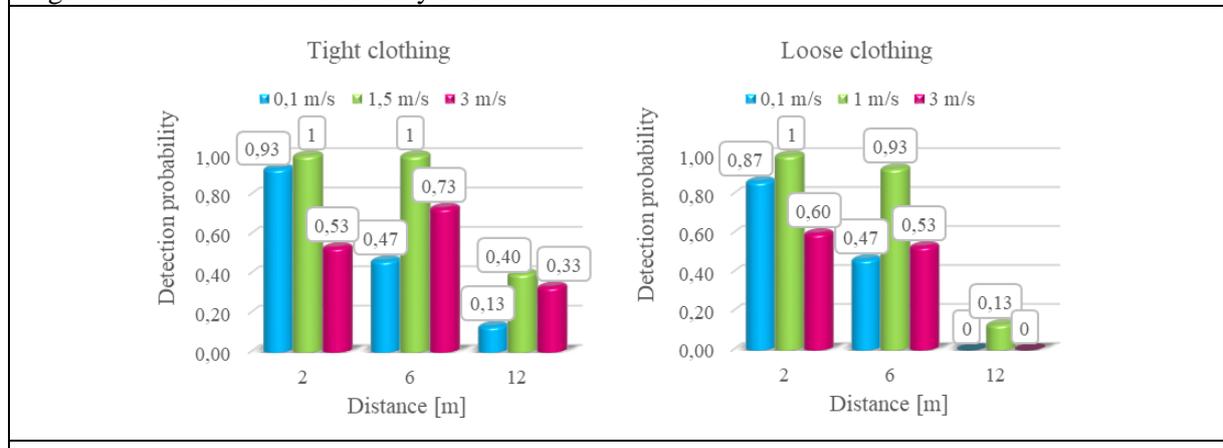| Figure 4: Verification of boundary of detection characteristic |
|---|
| |
| Source: authors |

Testing the probability of intruder detection

The standard defines that the detection target must be dressed in suitable tight clothing. In many cases, the intruder uses masking equipment, such as headwear. This is the reason why the probability of intruder detection was verified not only by detecting the target in tight clothing but also by detecting the target wearing loose clothing such as a hood.

Experimental testing was carried out by perpendicular movement of the person on the detector axis from three distances - 2, 6 and 12 meters. The person moved at three speeds. The speed of 0.1 m / s represents the minimum speed that the standard specifies. A speed of 1.5 m / s is the normal rate of walking. A speed of 3 m / s represents the maximum speed specified by the standard STN EN 50131-2-2. A comparison of the probability of detecting the Guardall DT15 PIR detector is shown in Figure 5.

Figure 5: Verification of boundary of detection characteristic
Source: authors

In the initial phase of the experimental testing, it was determined that the procedure for verifying the detection characteristic described in STN EN 50131-2-2 was insufficient. Due to asymmetric detection characteristics it was difficult to identify individual boundary points of the detection characteristic. For this reason, it is necessary to consider modifying the procedure described in the standard STN EN 50131-2-6. This procedure could be altered according to the procedure used within the experimental testing of the PIR detector Guardall DT15.

Several facts have been identified during the experimental testing of the PIR detector Guardall DT15. The most significant finding was that the probability of intruder detection on the area of the detection characteristic is not constant and therefore does not equal 1. Several factors influence the probability of intruder detection, especially the speed of movement and the distance in which the detection target (person, intruder) moves. In addition, the impact of clothing (tight or loose) is insignificant. The proposal for a change of standards is to tighten the requirements for PIR detectors of the 2nd security grade. Specifically, the minimum and maximum movement speed of target detection should be improved. Also, it is appropriate to reduce the close-range distance of the PIR detectors.

Conclusion

The results of experimental testing can be used not only for theory but also for the designers of intruder alarm systems. It is necessary to know all the limitations and weaknesses of the individual components for designing, evaluating and creating a reliable intruder alarm system. A thoroughly designed intruder alarm system prevents false alarms and increases the intruder detection success rate. The results of the experimental testing can serve as a tool for manufacturers to improve their products or tests procedures.

The result of the paper explains proposals for the modification of European standards for intruder alarm systems.Modifications could be affected by the very development of these componentswhich could be affected by the above-mentioned modifications. Manufacturers would have to comply with stricter conditions in production. Intruder alarm systems could become more effective in detecting an intruder in a secured area and more resilient to being overcome by these intruders.

References

Buchanan, R. C. (2004). *Ceramic Materials for Electronics.* Cincinnati: Marcel Dekker, Inc.

Garcia, M. L. (2006). *Vulnerability Assessment of Physical Systems.* Oxford, United Kingdom: Elsevier.

Hofreiter, L., & Krížovský, S. (2017). *Ochrana objektov.* Kosice: University of Security Management in Kosice.

Honey, G. (2007). *Intruders alarms.* Oxford, United Kingdom: Elsevier.

Křeček, S. a. (2006). *Příručka zabezpečovací techniky.* Blatná: Blatenská tiskárna.

Kucera, M., & Sebok, M. (2012). Electromagnetic compatibility analysis of electric equipments. (88), pp. 296-299.

Lovecek, T., Ristvej, J., Sventekova, E., Velas, A., & Siser, A. (2016). Research of Competencies of Crisis and Security Managers. In H. Zhang (Ed.), *3rd International Conference on Economic, Business Management and Education.54*, pp. 172-177. Prague: SINGAPORE MANAGEMENT & SPORTS SCIENCE INST PTE LTD.

Lovecek, T., Velas, A., Kampova, K., Maris, L., & Mozer, V. (2013). Cumulative Probability of Detecting an intruder by Alarm System. *47th Annual International Carnahan Conference on Security Technology.* Medellin: IEEE. doi:10.1109/CCST.2013.6922037

Loveček, T., Veľas, A., & Ďurovec, M. (2015). *Bezpečnostné systémy: poplachové systémy.* Žilina, Slovenská republika: EDIS - vydavateľstvo ŽU.

Medjdoub, F. (2017). *Gallium Nitride (GaN): Physics, Devices, and Technology.* Lille: CRC Press.

Michalec, L. (2013). *PIR detektor: Skvělý sluha, ale zlý pán.* Retrieved November 20, 2017, from HW.cz: http://www.hw.cz/automatizace/pir-cidlo-skvely-sluha-ale-zly-pan.html

Mokrý, K. (2018, February 13). Sales of intruder alarm systems. (M. Kutaj, Interviewer) Brno.

Svetlik, J., & Velas, A. (2016). The Safety Training in the Municipality. In L. Chova, A. Martinez, & I. Torres (Ed.), *8th International Conference on Education and New Learning Technologies* (pp. 1350-1355). Barcelona: IATED-INT ASSOC TECHNOLOGY EDUCATION A& DEVELOPMENT. doi:10.21125/edulearn.2016.1271

Velas, A. (2010). *Elektrické zabezpečovacie systémy.* Žilina: EDIS - vydavateľstvo ŽU v Žiline.

Velas, A. (2013). Hodnotenie účinnosti elektrických zabezpečovacích systémov pri ochrae objektov. Žilina, Slovakia: FŠI ŽU. Habilitation Thesis.

Velas, A., Kutaj, M., & Durovec, M. (2017). Influence of changing the parameters of the camera system on video-based motion detection. In A. Morales, R. Vera-Rodriguez, R. Lazzeretti, J. Fierrez, & J. OrtegaGarcia (Ed.), *International Carnahan Conference on Security Technology (ICCST).* Madrid: IEEE. doi:10.1109/CCST.2017.8167829